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RESEARCH ON CERTAIN SOIL-BORNE DISEASES AS AFFECTED BY OTHER MICRO-ORGANISMS[1]

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The object of this paper is to discuss briefly, from the viewpoint of the plant pathologist, some of the problems on soil-borne diseases as affected by antibiosis and related phenomena. An extensive review of the literature, most of which has appeared since 1930, will not be attempted, because several reviews are already available. One of the most recent of these is by Garrard and Lochhead (4). Therefore it is with a certain hesitation that the writer decided to base the present discussion mostly on familiar experimental results obtained by himself and colleagues.

During recent years plant pathologists have obtained evidence that certain fungi and bacteria may, in a soil, definitely suppress the virulence or growth of an associated pathogen. This and other related information has provided a new perspective concerning various research problems on soil-borne diseases.

It would appear that plant pathologists were rather slow to grasp the significance to soil-borne diseases of the results of Potter (13) in 1908, Fawcett (3) in 1923, and Porter (12) in 1924. Although Potter demonstrated that the growth products of one fungus applied to the surface of susceptible plant tissue would afford complete protection from its fungal parasite, and Fawcett that a species of *Fusarium* not parasitic to the citrus tree stimulated the virulence of *Pythiacystis citrophthora* Sm. and Sm. when associated, it was Porter who first demonstrated experimentally in a soil medium that certain bacteria common to soil afforded marked protection to the roots of wheat attacked by *Helminthosporium sativum* P.K. and B., and to those of flax by *Fusarium* sp. He also proved that this protective effect varied with the temperature of the soil. The importance of temperature has been confirmed and elaborated more recently by Machacek (9), Henry (7), and Garrett (5).

In an endeavour to explain the well known erratic behaviour of the common scab disease of potato in a soil medium, the author (14, 15) concluded from certain laboratory and field experiments that the severity of this disease might often be modified by the antagonistic effects of associated soil micro-organisms. The application of large amounts of green rye to a thoroughly infested soil, of about pH 5.1, did not perceptibly reduce the

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disease. As a matter of interest here, the writer, in a number of subsequent experiments in Alberta, has never been able to secure appreciable reduction of scab by this method. Millard and Taylor (10) in 1927 attempted to determine how green rye material in a sterilized soil might affect this disease, and came to the conclusion that the green manure itself was not effective, but functioned indirectly as a medium for a saprophyte (in this case *Actinomyces praecox*) which either starved out the pathogen by its more vigourous growth or was antibiotic to it.

In attempting to confirm the results just indicated, the writer on several occasions has been unable to secure control of scab by infesting both steam sterilized and natural soil containing different amounts of green rye or green clover with *A. scabies* or *A. praecox*. Moreover, these organisms seem to be perfectly compatible on potato dextrose agar, and also in a steam sterilized soil medium. Therefore, it is possible that the control of scab secured by Millard and Taylor was not affected directly by *A. praecox*, but by certain other undetermined micro-organisms favoured by the presence of *A. praecox* or by other conditions in their particular experiment. And since the matter of biological balance is involved, it is natural that the identical effective combination of micro-organisms might not always develop in subsequent repetitions of the same experiment, nor would it be easy for another to obtain similar results, especially when a different soil type is used.

SOME RECENT OBSERVATIONS ON VITIATION OF VIRULENCE OF INOCULA IN SOIL

As mentioned before, the results of some of the work in Alberta will be used to indicate the trend of recent progress in this field and the problems which confront the pathologist engaged in research on soil-borne diseases.

Year after year we were unable to secure satisfactory artificial infestation of field soil with *Ophiobolus graminis* Sacc., *Helminthosporium sativum* P. K. and B. and *Fusarium culmorum* (W. G. Sm.) Sacc. The virulence of the inoculum of each of these pathogens was apparently lost soon after it was put into field soil. Sometimes virulence was retained long enough to cause injury to the young seedlings, but, as a rule, not long enough to produce well marked disease symptoms on plants in post-seedling stage. In certain seasons there was practically no effect from the inoculum, even on the very young seedlings. Attempts to create disease gardens for each of these pathogens, by adding annually to the same plot a large quantity of inoculum, also failed completely. On the other hand, it was found that effective disease gardens could be established by this method for *A. scabies*, *Sclerotinia* sp. and for *Rhizoctonia solani* Kühn. But *Plenodomus meliloti* D. and S. and *Cylindrocarpon Ehrenbergi* Wr. did not appear to persist any better than did *O. graminis*, *H. sativum* or *F. culmorum*. The hypothesis was that the inoculum of *O. graminis*, *H. sativum* and *F. culmorum*, when placed in the field soil, was quickly vitiated by certain other soil flora, and those pathogens which were more successful in retaining their virulence and in persisting were not as susceptible to the antagonistic influences indicated.

The theory indicated was confirmed experimentally by Henry (6), and by Sanford and Broadfoot (17). In the latter experiments, 65 random

isolates, including bacteria, actinomycetes and fungi, were obtained from the soil of a wheat field, and tested to determine their ability to suppress the virulence of *O. graminis*, *H. sativum* and *F. culmorum* on wheat seedlings. The reaction of these isolates ranged from complete control to none, and a few seemed to increase the severity of the attack. In general, *O. garminis* was more susceptible to the association effects of the micro-organisms used than either *H. sativum* or *F. Culmorum*. Other results, not published, showed that all these pathogens did not necessarily react to a given isolate in the same way or to the same degree. It was found that the living cultures were decidedly more effective than their filtrates.

The foregoing information suggested a group of studies, one of the first of which was to determine the rate at which the virulence of *O. graminis* was vitiated in a steam sterilized soil and in a natural soil. By a systematic arrangement regarding time of planting and time of applying the inoculum, Broadfoot (1) found that although the inoculum was highly effective in a soil just steam-sterilized, its virulence was decreased by 77% when this soil was exposed to re-contamination for 10 days before being planted. When it was exposed for 20 days, the inoculum was reduced to 18% of its initial virulence. After 120 days, its effectiveness had practically vanished, and even the pathogen seemed to have disappeared from the soil. The initial effectiveness of the pathogen in unsterilized soil was 73% less than in sterilized soil, and after 30 days it was equally low in both soils.

In sharp contrast to the behaviour of *O. graminis*, *H. Sativum* and *F. culmorum*, experiments (16) have shown that inoculum of *R. Solani* is least pathogenic when added to a sterilized soil, but reaches its greatest virulence when it is mixed in natural soil in the relatively small proportion of 1 : 15. Also, it is highly significant that the growth of this pathogen is abundant in a sterilized soil, despite heavy recontamination by other micro-organisms, and that it is usually meagre by comparison in the natural soil. The evidence also indicated that the virulence of inoculum of *R. Solani* could remain practically undiminished in the natural soil mentioned during a period of 7 months, with or without the presence of the host. On the other hand, the virulence was often temporarily lost, despite the relative abundance of the pathogen, and the presence of the host, and, in certain cases, the pathogen appeared to disappear from the soil. Inoculum of *A. scabies* mixed in a sterilized soil, or in a natural one, usually continued to be very effective for at least 3 months under field conditions. Therefore, the results mentioned showed that a critical study of the behaviour of the inocula of various soil-inhabiting pathogens added to sterilized and also to natural soil would reveal important differences in their ability to persist or to remain pathogenic.

Again, there is considerable evidence that certain micro-organisms may be very antagonistic to a pathogen on synthetic agar, but in a soil they may not appreciably affect either the growth or the virulence of the parasite. For example, acids accumulate quite readily in toxic amounts on nutrient agar media, but in a soil substrate this is, for obvious reasons, very unlikely to occur. In other experiments made in a steam-sterilized soil, kept free from contamination, certain cultures of bacteria and also of fungi more or less completely suppressed the growth of *A. scabies*, *R. Solani*, *O. graminis*, *H. sativum*, *F. culmorum* or *Sclerotinia* sp. Certain cultures were effective against more than one of the pathogens mentioned, and a

few were specific. These results are mentioned to indicate the complexity of the effective operation of antibiosis in a natural soil and the danger of making general deductions for field practice from data secured by the use of synthetic media, or even of sterilized soil.

The results which Weindling (19, 20) secured with *Trichoderma lignorum* (Tode) Harz. and *R. Solani* furnish a good illustration of some of the uncertainties indicated. He proved that on synthetic media *T. lignorum* produced a substance which disorganized the cellular contents of *R. Solani*; that the young hyphae of the former parasitized the latter, and in soil controlled the damping off by *R. Solani* of certain susceptible plants. In the author's experiments it has been quite easy to demonstrate on synthetic media the effect on growth and cellular disorganization of toxic products produced by *T. lignorum* on *R. Solani*, but in soil, under controlled conditions, the strain of *T. lignorum* with which Weindling worked has not given any very definite evidence of controlling the virulence of *R. Solani* on potato sprouts. Also, on potato dextrose agar, *T. lignorum* produces a substance which is somewhat toxic to spores of *A. scabies*, but apparently this fungus has little or no effect on the growth of *A. scabies* in a sterilized soil, or on the development of the disease in natural field soil. In this connection, Daines (2) found that *T. lignorum* did not control either the rhizoctonia disease or common scab of potato under field conditions.

Although the present evidence suggests that antagonistic substances produced by associated micro-organisms are effective in a natural soil, there is the interesting possibility that certain recently discovered accessory growth products elaborated by plants and micro-organisms, may also play an important role in the degree of virulence which a pathogen may express at a given time, as well as in its persistence or its relative abundance in a given natural soil or crop sequence. In this connection, the discovery (21) of a universally occurring stimulant, known as pantothenic acid, and found in the cells of a great variety of animals, plants, and micro-organisms, is significant. But this is only one of several recently discovered growth-promoting substances. Of special interest is the conclusion of Starkey (18) and others, that substances of this nature are produced by the roots of certain plants, because, as already suggested, they may have an important relation to the pathogenicity of soil-inhabiting pathogens, and particularly to those specialized races weak in virulence. For instance Padwick (11) and Garrett (5) suggest that without certain of these accessory growth substances, presumably produced by the roots of host plants, *O. graminis* is unable to compete successfully with the other associated saprophytes in an unplanted soil, and, therefore, soon disappears. These and a host of other considerations, which even a casual examination brings to mind, indicate how incompletely is understood the behaviour of soil-inhabiting pathogens with regard to their persistence and their disease-producing capabilities in a natural soil, and, therefore, the need for careful research on these problems.

SIGNIFICANCE OF ANTIBIOSIS AND RELATED PHENOMENA TO RESEARCH PROBLEMS

Among the most valuable contributions to the study of diseases caused by soil-inhabiting pathogens to date is the demonstration of the rapid decline of the virulence of inoculum of *O. graminis*, *H. sativum*, and

F. culmorum in recontaminated sterilized soil and in a field soil, and also the fact that all the pathogens are not similar in this respect. These and other recent findings have made possible a clearer perspective of the problems associated with the study of the pathogenicity, growth and persistence of soil-inhabiting pathogens.

For example, the technique which has been used in testing for varietal resistance to root rots of cereals has been carefully examined and a serious attempt is being made to surmount the difficulties which until now were imperfectly understood. When inoculum is placed in sterilized soil, the pathogen exhibits marked virulence for a short time, and there is a high mortality of young seedlings as they emerge from the seed, or soon after, while other seedlings are permanently crippled before they get an opportunity to become established or to show any natural resistance which they may have. In spite of this, certain plants escape attack to a greater or lesser degree on account of the timely protection afforded them by other associated micro-organisms. In natural soil, the situation is similar, only more plants escape because of the increased protection which is given them. To avoid these pitfalls, we would, ideally, allow the seedling to become well established, then apply the inoculum and grow the plant to maturity. But, as already pointed out, the associated difficulties of technique, either under aseptic conditions or in natural field soil, are great, but perhaps not insurmountable. Let us hope that, in this case, to know one's difficulty will bring it nearer to solution.

In addition to providing a better understanding of some of the difficulties just indicated, the recent knowledge has stimulated our interest in how summerfallow, crop rotation, certain crop residues and fertilizers affect the increase, decrease or virulence of the various plant pathogens which inhabit the soil. For example, one asks why one year of summerfallow produces such a marked effect in reducing the damage of *O. graminis* in the wheat crop following it, but gives much less control of *H. sativum* and *F. culmorum*, no control of *Pythium* sp., and, in certain areas at least, no appreciable control of the potato diseases caused by *A. scabies* and *R. Solani*. Also, one wishes to know why oats and certain other crops produce such a marked controlling effect on the virulence of *O. graminis*, *H. sativum* and *F. culmorum*, and apparently no control on certain pathogens like *A. scabies* and *R. Solani*, and why both of the last named fungi become abundant in a given soil cropped to cereals only from the time it was first cultivated. If in these instances a host crop is not necessary, one asks how necessary is it for *O. graminis*, *H. sativum* or *F. culmorum*. These pathogens should be able to live saprophytically and possibly to increase on the remains of the preceding diseased crop of wheat in the moist summerfallow, but do they? Or, as Starkey (18) observed in the case of certain soil fungi, is the existence of their mycelia transitory and subject to destruction by bacteria and other lethal factors which are more effective in a summerfallow than in a soil cropped to wheat?

One might continue to apply the recent knowledge under discussion to many phases of plant pathology. For example, the Dominion Botanist, Dr. H. T. Güssow, has supplied the following interesting comment based on years of careful observation and studies of seed-borne diseases under his direction. "Almost all seeds, including champion and elite seeds, are con-

tinuously found to carry fungi of diverse kinds, even after a most effective surface sterilization has been practised. Thus, seeds obtained from certain regions of Canada may show alarming infestations by fungi, which are seriously destructive to the germination of the seeds under test, while samples from other regions show no such wide range of infestation and remain satisfactorily free from destructive organisms. From this angle, the behaviour of seeds from different areas clearly confirms the observation that the prevalence of serious root rots is at present not by any means uniformly important throughout Canada. Indeed, one might be justified in expecting serious calamities to result in our Canadian soils from planting the infested seed indicated, were it not for the various antibiotic levelling activities of nature which operate in the soil or in the rhizosphere. That this infestation has been fairly successful in certain soils and not in others, suggests beyond reasonable doubt the relative absence of unfavourable mechanical and chemical factors, or antibiotic micro-organisms in some instances, and the effectiveness of one or more of these factors in other soils."

In conclusion, it is clear that some of the important questions touched upon in this brief review offer the plant pathologist many attractive and challenging problems, the elucidation of which may have great practical application to agriculture and scientific value as well. Without this knowledge many of those important diseases caused by soil-inhabiting pathogens must continue to be very inadequately understood and, in general, baffling under field, greenhouse and laboratory conditions. Indeed, it seems certain that the value of a large amount of past investigation on the diseases indicated has been lost through a lack of knowledge of the limits of the technique employed or the fundamentals which would enable a proper interpretation of the data obtained. For example, many repetitions of the same experiment, and a liberal provision for controls, are now recognized as safeguards necessary to even approximately accurate interpretation.

With the yard-stick of pathogenicity, the pathologist can measure indirectly the rise or fall of virulence, and in many cases, the persistence of the soil pathogens over a given period in a given soil which has a known original infestation. Also, he can observe the effect of types of soil and food, of micro-organisms, and of certain other plants and their debris on the pathogenic behaviour of soil-inhabiting pathogens. This would seem the legitimate field of work for the plant pathologist. Meanwhile, the soil microbiologist will wish to explore the more extensive territory and discover the fundamental factors which determine the rise and fall of the soil's population and other relative factors. The results obtained by plant pathologists and soil microbiologists will be mutually beneficial.

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INVESTIGATIONS IN SAMPLING SOILS PREVIOUSLY FERTILIZED FOR FLUE-CURED TOBACCO[1]

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Chemical soil testing to determine the levels of soil nutrients for guidance in fertilization for crop needs has been emphasized during recent years. Efforts have been devoted chiefly to devising new methods of analysis and improving existing ones to make them more suitable for the particular soil or crop in question. The taking of the soil sample in the field is, however, of equal, if not greater, importance in obtaining a reliable test. The most accurate soil analysis cannot reveal the true character and condition of the soil unless the sample analysed is representative of the soil in the area under study.

The literature reveals little information regarding the relative effectiveness of different methods of sampling. Since sampling technique for soil fertility studies in fertilizer plots is by no means standardized, one may be led to question the validity of conclusions drawn by investigators who fail to appreciate the necessity of accuracy in selecting samples. A number of years ago it was found (3) that, despite unusual care, the sampling error remained greater than the analytical error. Results of numerous chemical tests on soils at the Delhi Substation have shown the inadequacy of ordinary methods for sampling land previously fertilized for flue-cured tobacco. Consequently, this subject has been given considerable study during the past two years.

EXPERIMENTAL WORK

Under ordinary farm conditions where commercial fertilizer is used in moderate amounts and is broadcast or uniformly applied with the seed drill, sampling may present no special problem. In dealing with a heavy feeding row crop such as tobacco, however, where from 800 to 1000 pounds of fertilizer per acre is localized in or near the row, there is encountered a real difficulty in obtaining a sample of soil which contains the average amount of nutrients and which accordingly gives a representative picture of the entire area. It can be realized readily that if a sample is taken at or near the location of a row, the results of analysis may prove misguiding in that they indicate a higher level of nutrients than is actually present throughout the soil as a whole. Although it may be expected that such increased concentration of nutrients in the location of the row soon disappears, tests conducted on a series of $\frac{1}{32}$-acre fertilizer plots on the Delhi Substation show that such is not the case. On the contrary, the differences persist for a long period following fertilization and are evident to some extent even after thorough cross cultivation. The results summarized in Table 1 support this conclusion. The figures represent the average levels of nutrients for ten plots.

[1] A joint contribution of the Dominion Experimental Substation, Delhi, Ontario, the Department of Chemistry, Ontario Agricultural College, Guelph, Ontario, and the Tobacco Division, Central Experimental Farm, Ottawa, Ontario, presented at the annual meeting of the Standing Committee on Tobacco Fertilizers for Ontario, held at Simcoe on December 7, 1938.

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TABLE 1.—AVERAGE NUTRIENT LEVELS AT DIFFERENT DATES IN VARIOUS POSITIONS WITH RESPECT TO THE ROWS WHERE FERTILIZER WAS APPLIED FOR FLUE-CURED TOBACCO

Date of sampling	Pounds readily soluble P_2O_5 per acre			Pounds replaceable K_2O per acre		
	On the row	10″ from row	20″ from row	On the row	10″ from row	20″ from row
June 8, 1937	39	28	25	188	78	52
July 26, 1937	41	34	25	190	87	101
Sept. 3, 1937	34	25	25	164	94	94
April 22, 1938	32	23	16	195	133	106
May 14, 1938	25	23	21	178	152	109

Fertilizer was applied at the rate of 1000 pounds per acre in the rows during May, 1936, and no additional fertilizer was added during the period in which the tests were conducted. The land was single-disced and rye was sown in the fall of 1936 after the tobacco was harvested. The plots were first sampled the following spring (1937), approximately 13 months after the fertilizer was applied. The second sampling, on July 26, was made immediately after a ripe crop of rye was disced down, and the third sampling on September 3 when the resulting volunteer crop of rye had reached almost its maximum autumn growth. Two additional samplings were made in the spring of 1938, the first on April 22 just before ploughing, and the last on May 14 after the land was cross ploughed and thoroughly cultivated. The samples were taken in the same manner each time, at the positions indicated. Since the rows were 40 inches apart, the position 20 inches from the row was approximately midway between the rows.

The replaceable potash was determined by Morgan's method (5), and the readily soluble phosphate by the modified Thornton method (6), both methods being altered so as to give numerical expressions of the actual amounts of nutrients found in the soil by these methods. In each case, the line and colour charts were substituted with known standards.

The figures presented in Table 1 indicate that there is a definite trend toward lower levels of both phosphate and potash as the distance from the location of the row increases, the samples taken on the rows showing much higher levels throughout. It should be noted that this gradation persists to a marked extent for almost 2 years after the fertilizer application, and that only after thorough cross cultivation as in the case of the final sampling are the differences considerably reduced. These results indicate that much of the fertilizer not taken up by the plant remains fairly well localized for a considerable length of time.

The problem as to how to obtain from plots such as these samples of soil which are truly representative of the whole plot, presents itself. It might be assumed that as long as the samples are comparable to one another nothing further is required, and that this condition could be fulfilled by taking all the samples at definite locations relative to the rows; for example, either directly on the rows or midway between them. This possibility was investigated and several difficulties were encountered. First of all, there was the inherent difficulty in finding the exact location of the rows.

This difficulty is appreciable, particularly when a dense crop of rye is growing, as is the case when the majority of the fields are sampled. The major difficulty, however, was found in obtaining uniformity in sampling. Samples from each plot were taken from 4 different locations which were, as nearly as possible, in the same position relative to the rows. These were mixed thoroughly to make a composite sample. A second composite sample was taken from the same plot and in the same manner. On testing for phosphate and potash, significant differences were found between the 2 samples. This held true also when the samples were taken from between the rows.

Bear and Salter (2), using a soil auger for sampling, chose 6 composite samples, each consisting of 38 borings distributed at regular intervals over a plot of $\frac{1}{10}$-acre, and found that the amounts of carbon, nitrogen, and phosphorus were quite uniform in 5 of the 6 composites. Bear and McClure (1) found that within certain limits the number of samples entering into the composite was not as important as that of having the samples, taken at different times to represent a plot, selected from the same locations. In this work, however, no mention was made of the manner in which the plots had been previously fertilized. Moreover, the taking of subsequent samples from exactly the same location each time, if not impractical, is at least subject to many obvious difficulties under farm conditions.

It was hoped that some of these difficulties might be overcome by taking a large number of samples at random over the entire plot. Random sampling obviates the necessity of determining the former location of the rows or of previous samplings, and the large number of samples in the composite should tend to level out the irregularities in individual portions. Since it would be inconvenient to use the spade slice method for taking a large number of samples, a $1\frac{1}{2}$-inch soil auger was employed. This auger proved to be quite satisfactory with the soil at the substation, which is of the Fox coarse sand type containing no stones.

In order to test this method of sampling, a $\frac{1}{40}$-acre plot was selected on new land recently acquired by the Substation. This land was well-suited for the purpose since previous to its present application it had received no fertilization for over 20 years, and its fertility level approximated that of virgin soil. The plot selected received a 2-10-8 fertilizer at the rate of 1000 pounds per acre, which was applied with the fertilizer drill in rows 40 inches apart. The plants were set in the resulting ridge.

Three weeks after the fertilizer was applied the plot was sampled by taking 50 borings, to a depth of 6 inches, at random over the plot. Then another 50 borings were taken in the same manner from the same plot. Each of these composite samples was separately and thoroughly mixed before testing. The mixing was at first done in a pail with a trowel, but this was found to be inadequate since the sample did not test uniformly throughout. The method of mixing, which was found satisfactory and finally adopted, was to screen the sample, then place it on a long sheet of wrapping paper on the floor, and roll the soil back and forth over the paper at least a dozen times. As may be noted in Table 2, the 2 samples proved different when analysed. Consequently, two additional samples consisting of 100 borings each were taken from the same plot. This time the results for the 2 samples were in agreement.

Later in the season, when the growing plants had absorbed some of the nutrients and when the fertilizer was dissolved to some extent in the soil solution, it was believed that the number of borings might be reduced without a great sacrifice in accuracy. Consequently, on July 25, ten weeks after fertilization, which was at the time of topping the tobacco, samples were taken in the same manner as before, except that the number of borings per sample was reduced to 50. Since these samples gave identical results, this method of sampling was adopted for the remainder of the season.

The suitability of this method for sampling a field, fertilized for tobacco the previous season and on which rye was growing, was investigated. A fertilizer plot supporting a good growth of rye was selected and borings were taken just before the rye was ripe. It was found on this plot that the number of borings could not be safely reduced below 25 per sample, but when 25 or more were taken, agreement between samples was obtained.

The results of the analysis of the samples, taken at the times and by the methods outlined above, are presented in Table 2.

TABLE 2.—RESULTS OF ANALYSIS OF COMPOSITE SOIL SAMPLES TAKEN BY DIFFERENT METHODS AND AT DIFFERENT LENGTHS OF TIME AFTER FERTILIZATION

No. of borings per sample	Pounds replaceable K_2O per acre			Pounds readily soluble P_2O_5 per acre		
	3 wks.†	10 wks.†	14 mos.‡	3 wks.†	10 wks.†	14 mos.‡
10			84			18
10			96			32
25			96			23
25			96			23
50	145	48		46	23	
50	96	48		27	23	
100	120			27		
100	120			27		
On the rows	385		192	180		46
10″ from rows	96		72	18		27
20″ from rows	72		84	18		27

† All samples taken 3 weeks and 10 weeks following the application of fertilizer were taken from the same plot.

‡ All these samples were from a plot which had received a similar fertilizer treatment 14 months previously and which was supporting a crop of rye at the time of sampling.

Samples were taken from the same plots, by the spade slice method, in 3 different positions relative to the rows, and the figures in Table 2 show the wide differences among them.

In order to ascertain what correlation could be obtained between fertilizer treatment and soil tests when this method of sampling (100 borings at random per plot) was used, a series of $\frac{1}{40}$-acre plots was sampled about 6 weeks after the fertilizer had been applied. The series consisted of plots which received increasing amounts of phosphate and potash, both separately and together. Superphosphate and sulphate of potash were applied to

supply phosphate and potash, respectively. These materials were broadcast and disced into the soil one week before making the basal application of fertilizer. The basal application (1000 pounds per acre of commercial 2-10-8) was applied in rows 40 inches apart with the fertilizer drill. Table 3 shows the results of analysis by the rapid methods mentioned previously in this paper (5, 6), as well as by the longer laboratory methods of Volk and Truog (8) for replaceable potash, and of Lohse and Ruhnke (4) for the extraction of readily soluble phosphate. The phosphorus in the extract was determined by the colorimetric method developed by Deniges and improved upon by Truog and Meyer (7).

TABLE 3.—COMPARISON OF ANALYSIS OF COMPOSITE SAMPLES, EACH COMPRISED OF 100 BORINGS AT RANDOM, FROM PLOTS WHICH HAD RECEIVED DIFFERENT FERTILIZER TREATMENTS SIX WEEKS PREVIOUS TO SAMPLING

Fertilizer treatment†	Lbs. replace. K_2O per ac.				Lbs. read. sol. P_2O_5 per ac.			
	Rapid		Lab.		Rapid		Lab.	
	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2
Basal (1000# 2-10-8)	96	72	81	84	23	30	115	128
Basal plus 100# P_2O_5	96	96	81	97	27	27	137	115
Basal plus 200# P_2O_5	96	72	92	79	46	54	167	174
Basal plus 100# K_2O	120	120	119	132	18	27	110	96
Basal plus 200# K_2O	193	193	192	164	23	27	133	117
Basal plus { 100# P_2O_5 + 100# K_2O	120	120	111	120	18	27	115	124
Basal plus { 200# P_2O_5 + 200# K_2O	193	193	168	162	23	30	110	110

† Amounts per acre on duplicate plots (Replicates 1 and 2 above).

The table shows that the agreement between the fertilizer treatments and the results of analysis by both methods is both reasonably close and fairly consistent. This agreement is quite considerably better than has been obtained previously by the writers, when the spade slice method was used and only 4 or 5 samples were taken to make up the composite sample.

SUMMARY

Data are presented which show the persistence of increased concentrations of nutrients in the zone of application where land is fertilized heavily in rows. A technique for sampling the soil of such areas is suggested. The results of analyses indicate that provided the area is uniform in type and topography representative samples may be obtained 3 weeks after fertilization by sampling at random in at least 100 places over the entire area. Ten weeks after fertilization, it appears that the number of places may be reduced to 50. It is indicated that this number may be reduced to 25 one or more years after fertilization. Analyses of composite samples, taken according to this procedure and showing fairly consistent agreement with fertilizer treatment, are shown.

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DIGESTIBILITY STUDIES WITH RUMINANTS

IV. PLANE OF NUTRITION AND DIGESTIBILITY OF CORN SILAGE

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INTRODUCTION

In a previous paper (4) the effect of the plane of nutrition on the digestibility of mangels was determined by feeding them at various levels with a constant ration of hay. It was found that the digestibility was unaffected by the amount consumed. In a similar but more extended investigation, the effect of the plane of nutrition upon the digestibility of corn silage has been determined. Three experiments were conducted. In one, corn silage was fed as the sole ration; in the second, the ration consisted of corn silage and hay in a constant ratio; and in the third, increasing quantities of corn silage were added to a constant ration of hay.

Apparently the only reference in the literature to the effect of the plane of nutrition upon the digestibility of silage, is that of Jordan and Jentner (1), at the New York State Agricultural Experiment Station. In their investigation they fed a ration containing between 75 and 80% of corn silage at two different levels to sheep. At the higher levels, the digestibilities were lower than at the lower levels.

EXPERIMENTAL

In this paper, each of the three experiments will be described separately. In all cases the experimental animals were grade Shorthorn steers.

Experiment 1—Effect of the Plane of Nutrition upon the Digestibility of Corn Silage when Fed as the Sole Ration

In the first experiment, in which corn silage was fed as the sole ration, it was planned to use five levels, namely, 8 kilos, 14 kilos, 20 kilos, 26 kilos, and *ad libitum* per animal per day, in a 5 × 5 Latin square. After two periods, however, it was found that the steers were not consuming the higher levels of corn silage. The experiment was, therefore, re-cast using only four levels, namely, 8 kilos, 14 kilos, 20 kilos, and *ad libitum*, per animal per day in a 4 × 4 Latin square. Animal 5 was removed from the experiment, leaving Animals 1, 2, 3, and 4. In an effort to obtain further values at very high levels of feeding, Animal 5 was given a good ration of hay, silage and grain during Period 3. Then in Period 4 the silage was given *ad libitum*. In this way a level of feeding was obtained which corresponded to Level V in the original 5 × 5 Latin square.

The technique of using *ad libitum* feeding in digestion trials was discussed in the previous paper on mangels (4). Up to and including the morning feed of the first day of the collection period, the animals were fed

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a constant amount of silage daily. The quantity chosen represented the utmost which the animals could consume consistently. From this point up to and including the morning feed of the fourth day before the end of the collection period, the animals were fed each day all they could consume on that day. During the remainder of the collection period, the animals received the original constant level.

In Table 1 is presented the feeding schedule. The levels of feeding have been numbered I, II, III, IV, and V. Level IV in the first two periods corresponds to the *ad libitum* level in the remaining periods. The figures in bold face type represent the 4 × 4 randomized Latin square. Due to a varying moisture content in the silage throughout the season, it was necessary to adjust the quantities fed for any one level from period to period.

TABLE 1.—FEEDING SCHEDULE OF EXPERIMENT ONE

(Daily rations in kilogrammes; Roman Numerals indicate plane; 4 × 4 square indicated by bold face type.)

Period	Animal 1		Animal 2		Animal 3		Animal 4		Animal 5	
1	26	(IV)	14	(II)	8	(I)	32[1]	(V)	20	(III)
2	8	(I)	25[2]	(V)	20	(III)	14	(II)	23.28[3]	(IV)
3	**8**	**(I)**	**20**	**(III)**	**24.25**	**(IV)**	**14**	**(II)**	–	
4	**21**	**(III)**	**25.17**	**(IV)**	**15**	**(II)**	**8.5**	**(I)**	26.83[4]	(V)
5	**26.17**	**(IV)**	**16**	**(II)**	**9**	**(I)**	**22**	**(III)**	–	
6	**15**	**(II)**	**9**	**(I)**	**21**	**(III)**	**25.83**	**(IV)**	–	

NOTES—

[1] Daily feed refusal of 0.139 kilogrammes.
[2] Daily feed refusal of 1.177 kilogrammes.
[3] Daily feed refusal of 1.008 kilogrammes.
[4] Daily feed refusal of 0.364 kilogrammes.

The experimental animals were $3\frac{1}{2}$ years old and numbered 1 to 5 in the experiment. Their average weights over the whole experiment were 512, 588, 552, 545, and 589 kilogrammes, respectively.

The complete data will be found in Tables 16, 17, and 18, in the appendix. In Tables 2 and 3 is presented a summary of all the coefficients of digestibility, while Table 4 gives the analysis of variance of the coefficients of digestibility of corn silage in the 4 × 4 Latin square.

TABLE 2. COEFFICIENTS OF DIGESTIBILITY OF CORN SILAGE. EXPERIMENT ONE

(Coefficients in per cent; animal numbers shown in brackets; 4 × 4 square indicated by bold face type.)

Period	Level I	Level II	Level III	Level IV	Level V	Mean	
						4 × 4 Square	Total
				DRY MATTER			
1	69.9 (3)	71.1 (2)	68.3 (5)	67.1 (1)	61.4 (4)	—	67.6
2	71.6 (1)	69.1 (4)	67.7 (3)	60.5 (5)	61.9 (2)	—	66.2
3	**71.3 (1)**	**69.8 (4)**	**65.5 (2)**	**64.0 (3)**	—	67.7	67.7
4	**71.9 (4)**	**68.1 (3)**	**65.8 (1)**	**64.1 (2)**	61.7 (5)	67.5	66.3
5	**70.5 (3)**	**65.9 (2)**	**64.8 (4)**	**61.3 (1)**	—	65.6	65.6
6	**67.1 (2)**	**64.5 (1)**	**63.3 (3)**	**63.1 (4)**	—	64.5	64.5
Mean 4 × 4 square	**70.2**	**67.1**	**64.9**	**63.1**	—	66.31	—
Total mean	70.4	68.1	65.9	63.4	61.7	—	66.3

TABLE 2.—COEFFICIENTS OF DIGESTIBILITY OF CORN SILAGE. EXPERIMENT ONE—Conc.

Period	Level I	Level II	Level III	Level IV	Level V	Mean	
						4 × 4 square	Total
ORGANIC MATTER							
1	72.3 (3)	73.4 (2)	70.8 (5)	69.3 (1)	63.6 (4)	—	69.9
2	73.7 (1)	71.2 (4)	69.9 (3)	62.6 (5)	63.9 (2)	—	68.3
3	**73.5 (1)**	**72.0 (4)**	**67.8 (2)**	**66.2 (3)**	—	69.9	69.9
4	**74.4 (4)**	**70.9 (3)**	**68.9 (1)**	**67.1 (2)**	64.6 (5)	70.3	69.2
5	**72.2 (3)**	**68.8 (2)**	**67.6 (4)**	**64.8 (1)**	—	68.4	68.4
6	**69.4 (2)**	**67.6 (1)**	**66.6 (3)**	**66.1 (4)**	—	**67.4**	**67.4**
Mean 4 × 4 square	**72.4**	**69.8**	**67.7**	**66.1**	—	**68.99**	—
Total mean	72.6	70.7	68.6	66.0	64.0	—	68.9
NITROGEN							
1	56.0 (3)	58.4 (2)	57.3 (5)	56.1 (1)	55.3 (4)	—	56.6
2	54.3 (1)	57.4 (4)	54.0 (3)	54.6 (5)	55.0 (2)	—	55.1
3	**52.3 (1)**	**56.3 (4)**	**48.2 (2)**	**52.0 (3)**	—	52.2	52.2
4	**49.6 (4)**	**46.2 (3)**	**54.9 (1)**	**53.0 (2)**	49.4 (5)	50.9	50.6
5	**48.6 (3)**	**50.5 (2)**	**52.6 (4)**	**51.2 (1)**	—	50.7	50.7
6	**50.0 (2)**	**48.6 (1)**	**46.7 (3)**	**50.7 (4)**	—	49.0	49.0
Mean 4 × 4 square	**50.1**	**50.4**	**50.6**	**51.7**	—	50.71	—
Total mean	51.8	52.9	52.3	52.9	53.2	—	52.6
ETHER EXTRACT							
1	77.3 (3)	78.0 (2)	78.3 (5)	79.0 (1)	78.3 (4)	—	78.2
2	76.3 (1)	77.0 (4)	76.6 (3)	75.3 (5)	76.8 (2)	—	76.4
3	**75.0 (1)**	**75.2 (4)**	**77.3 (2)**	**77.7 (3)**	—	76.3	76.3
4	**71.8 (4)**	**77.3 (3)**	**77.7 (1)**	**77.7 (2)**	75.6 (5)	76.1	76.0
5	**79.7 (3)**	**76.9 (2)**	**79.9 (4)**	**77.9 (1)**	—	78.6	78.6
6	**76.0 (2)**	**78.2 (1)**	**78.9 (3)**	**79.4 (4)**	—	78.1	78.1
Means 4 × 4 square	**75.6**	**76.9**	**78.5**	**78.2**	—	77.29	—
Total means	76.0	77.1	78.1	77.8	76.9	—	77.2
CRUDE FIBRE							
1	61.3 (3)	66.7 (2)	62.4 (5)	58.6 (1)	47.7 (4)	—	59.3
2	66.2 (1)	65.1 (4)	62.0 (3)	48.9 (5)	47.2 (2)	—	57.9
3	**68.5 (1)**	**65.1 (4)**	**57.5 (2)**	**54.3 (3)**	—	61.4	61.4
4	**72.8 (4)**	**67.0 (3)**	**63.3 (1)**	**60.4 (2)**	56.9 (5)	65.9	64.1
5	**65.8 (3)**	**61.3 (2)**	**59.7 (4)**	**55.3 (1)**	—	60.5	60.5
6	**63.9 (2)**	**63.1 (1)**	**62.0 (3)**	**59.9 (4)**	—	62.2	62.2
Means 4 × 4 square	**67.8**	**64.1**	**60.6**	**57.5**	—	62.49	—
Total means	66.4	64.7	61.2	56.2	50.6	—	60.8
N-FREE EXTRACT							
1	78.3 (3)	77.6 (2)	75.4 (5)	74.6 (1)	70.4 (4)	—	75.3
2	78.9 (1)	75.2 (4)	74.7 (3)	68.9 (5)	71.5 (2)	—	73.8
3	**77.9 (1)**	**76.6 (4)**	**73.5 (2)**	**72.4 (3)**	—	75.1	75.1
4	**78.1 (4)**	**75.7 (3)**	**73.1 (1)**	**71.6 (2)**	69.7 (5)	74.6	73.6
5	**77.6 (3)**	**73.9 (2)**	**72.1 (4)**	**70.2 (1)**	—	73.5	73.5
6	**74.3 (2)**	**71.6 (1)**	**70.5 (3)**	**70.3 (4)**	—	71.7	71.7
Means 4 × 4 square	**77.0**	**74.5**	**72.3**	**71.1**	—	73.71	—
Total means	77.5	75.1	73.2	71.3	70.5	—	73.9

From Table 2 it will be noticed that as the plane of nutrition increased there was a progressive decrease in the digestibility of the dry matter, organic matter, crude fibre, and nitrogen-free extract. The values for the

TABLE 3.—MEAN COEFFICIENTS OF DIGESTIBILITY FOR EACH ANIMAL FOR 4 × 4 SQUARE
(Coefficients in per cent.)

—	Animal 1	Animal 2	Animal 3	Animal 4
Dry matter	65.7	65.7	66.5	67.4
Organic matter	68.7	68.3	69.0	70.0
Nitrogen	51.8	50.4	48.4	52.3
Ether Extract	77.2	77.0	78.4	76.6
Crude Fibre.....	62.6	60.8	62.3	64.4
N-free Extract.....	73.2	73.3	74.1	74.3

TABLE 4.—ANALYSIS OF VARIANCE OF COEFFICIENTS OF DIGESTIBILITY OF CORN SILAGE FOR 4 × 4 SQUARE. EXPERIMENT ONE

For $n_1 = 3, n_2 = 6; z = 0.7798$ and 1.1401 at P of 0.05 and 0.01, respectively

Nutrient	Variance due to	F	Sums of squares	Variance	$\frac{1}{2}\log_e V$	Z compared to error
Dry matter	Plane	3	112.1936	37.3979	1.8108	2.2572
	Period	3	28.5136	9.5045	1.1259	1.5723
	Animal	3	7.8736	2.6245	$\overline{0}.4825$	0.9289
	Error	6	2.4568	0.4095	$\overline{1}.5536$	
	Total	15	151.0376			
Organic matter	Plane	3	89.2016	29.7339	1.6961	1.9134
	Period	3	21.6816	7.2272	0.9889	1.2062
	Animal	3	6.3216	2.1072	$\overline{0}.3727$	0.5900
	Error	6	3.8848	0.6475	$\overline{1}.7827$	
	Total	15	121.0896			
Nitrogen	Plane	3	5.8416	1.9472		
	Period	3	20.7216	6.9072		
	Animal	3	36.5936	12.1979		
	Error	6	52.3008	8.7168		
	Total	15	115.4576			
Ether extract	Plane	3	21.2016	7.0672	0.9777	0.5045
	Period	3	19.0736	6.3579	0.9249	0.4517
	Animal	3	7.2016	2.4005	0.4378	
	Error	6	15.4608	2.5768	0.4732	
	Total	15	62.9376			
Crude fibre	Plane	3	237.0416	79.0139	2.1848	1.6630
	Period	3	67.4416	22.4805	1.5563	1.0345
	Animal	3	26.2096	8.7365	1.0838	0.5620
	Error	6	17.0368	2.8395	0.5218	
	Total	15	347.7296			
N-free extract	Plane	3	80.9936	26.9979	1.6479	2.8017
	Period	3	27.2336	9.0779	1.1029	2.2567
	Animal	3	3.7136	1.2379	$\overline{0}.1067$	1.2605
	Error	6	0.5968	0.0995	$\overline{2}.8462$	
	Total	15	112.5376			

coefficients of digestibility of the nitrogen were reasonably constant, with, however, a tendency to be slightly higher at the higher levels. In the same way the values for the ether extract tended to be slightly higher at the higher levels. From the analysis of variance, in Table 4, it will be observed that the decrease in digestibility for dry matter, organic matter, crude fibre, and nitrogen-free extract, was statistically significant, whereas there was no significant effect of the plane of nutrition upon the digestibility of either nitrogen or ether extract. Further, there was in general a significant difference due to period and in some cases due to the individuality of the animals.

In order to obtain a picture of the overall effect of the plane of nutrition, the total digestible nutrients in per cent of dry matter for the 4 × 4 Latin square have been presented in Table 5 with the analysis of variance in Table 6. There was a statistically significant decrease in the T. D. N. as the plane of nutrition was increased.

TABLE 5.—TOTAL DIGESTIBLE NUTRIENTS IN CORN SILAGE EXPRESSED AS PERCENT OF DRY MATTER, FOR 4 × 4 SQUARE

(Animal numbers in brackets)

—	Level I	Level II	Level III	Level IV	Means
Period 1	70.97 (1)	69.61 (4)	65.33 (2)	64.14 (3)	67.51
Period 2	71.85 (4)	68.99 (3)	67.17 (1)	65.39 (2)	68.35
Period 3	70.06 (3)	66.72 (2)	65.57 (4)	63.10 (1)	66.36
Period 4	67.56 (2)	65.82 (1)	64.79 (3)	64.43 (4)	65.65
Means	70.11	67.79	65.72	64.27	66.97

Mean for Animal 1—66.77
Mean for Animal 2—66.25
Mean for Animal 3—67.00
Mean for Animal 4—67.87

TABLE 6.—ANALYSIS OF VARIANCE OF TOTAL DIGESTIBLE NUTRIENTS IN DRY MATTER OF CORN SILAGE

For $n_1 = 3$, $n_2 = 6$, $z = 0.7798$ and 1.1401 at P of 0.05 and 0.01, respectively

Variance due to	F	Sums of squares	Variance	$\frac{1}{2} \log_e V$	z compared to error
Plane	3	77.5380	25.8460	1.6261	1.9305
Period	3	17.2420	5.7473	0.8744	1.1788
Animal	3	5.4772	1.8257	0.3010	0.6054
Error	6	2.2638	0.5440	$\bar{1}$.6956	
Total	15	103.5210			

Using the method of Petersen, as modified by Stothart (2), for computing money values of feeds on the basis of digestible nutrients, the values of the corn silage at the four levels were calculated. As a basis for the calculation, barley at a current market price of $20.00 per ton and soybean oil meal (expeller process) at a current market price of $35.00 per ton, were used. Expressed on the original basis of 23.37% dry matter, the values of the corn silage at the four levels of I to IV in the 4 × 4 square were, respectively, $3.74, $3.64, $3.54, $3.49, representing a loss from the lowest to the highest level of feeding of 6.68%.

Experiment 2. Effect of the Plane of Nutrition upon a Ration of Hay and Corn Silage fed in Constant Ratio

In the second experiment, the effect of the plane of nutrition upon a ration of hay and corn silage in the ratio of 4 to 5 was determined. Four levels of feeding were used, namely, I, II, III, and IV. Level IV was the maximum amount which the animals would consume each day without waste. Level I consisted of 2 kilogrammes of hay and 2.5 kilogrammes of corn silage. The other two levels were intermediate. Determinations were also made of the digestibility of the hay alone and of the corn silage alone making a total of 6 different rations. The experiment was set up in the form of a 6 × 6 randomized Latin square and the feeding schedule is given in Table 7.

TABLE 7.—FEEDING SCHEDULE FOR EXPERIMENT 2

(Daily rations in kilogrammes. Roman numerals in brackets indicate level of feeding for mixed rations)

Period	Feed	Animal 1	Animal 2	Animal 3	Animal 4	Animal 5	Animal 6
1	Hay	6.00 (IV)	0.00	5.00 (III)	3.48 (II)	7.00	2.00 (I)
	Silage	7.50	20.00	6.25	4.35	0.00	2.50
2	Hay	3.48 (II)	2.00 (I)	7.00	0.00	5.00 (III)	6.00 (IV)
	Silage	4.35	2.50	0.00	20.00	6.25	7.50
3	Hay	5.00 (III)	3.48 (II)	0.00	2.00 (I)	6.00 (IV)	7.00
	Silage	6.25	4.35	20.00	2.50	7.50	0.00
4	Hay	0.00	7.00	2.00 (I)	6.00 (IV)	3.48 (II)	5.00 (III)
	Silage	20.00	0.00	2.50	7.50	4.35	6.25
5	Hay	7.00	6.75 (IV)	3.48 (II)	5.00 (III)	2.00 (I)	0.00
	Silage	0.00	8.438	4.35	6.25	2.50	20.00
6	Hay	2.00 (I)	5.00 (III)	6.75 (IV)	7.00	0.00	3.48 (II)
	Silage	2.50	6.25	8.438	0.00	20.00	4.35

The animals were two and one-half years old and numbered 1 to 6 in the experiment. Their average weights were 489, 548, 493, 510, 536, and 545 kilogrammes, respectively.

The complete data will be found in Tables 19, 20, 21, and 22, in the appendix. In Tables 8 and 9 is given a summary of the coefficients of digestibility, with the analysis of variance in Table 10, and the necessary differences in Table 11.

TABLE 8.—COEFFICIENTS OF DIGESTIBILITY OF TOTAL RATIONS ARRANGED BY ANIMALS AND BY LEVELS. EXPERIMENT 2

(Coefficients in per cent, periods shown in brackets)

Nutrient	Animal	Hay	Silage	Mixed ration				Means
				Level I	Level II	Level III	Level IV	
Dry matter	1	56.1 (5)	64.4 (4)	58.5 (6)	58.7 (2)	59.6 (3)	58.3 (1)	59.3
	2	57.3 (4)	65.0 (1)	60.4 (2)	58.9 (3)	59.1 (6)	58.3 (5)	59.8
	3	56.1 (2)	61.3 (3)	61.9 (4)	62.4 (5)	61.1 (1)	60.5 (6)	60.6
	4	59.5 (6)	65.6 (2)	62.0 (3)	61.9 (1)	61.5 (5)	59.9 (4)	61.7
	5	57.6 (1)	64.2 (6)	62.0 (5)	60.3 (4)	60.2 (2)	58.8 (3)	60.5
	6	56.4 (3)	66.9 (5)	62.3 (1)	62.2 (6)	61.3 (4)	59.1 (2)	61.4
	Mean	57.2	64.6	61.2	60.7	60.5	59.2	60.54
	S.E.	±0.53	±0.76	±0.60	±0.68	±0.40	±0.36	
	C.V.	2.28	2.90	2.41	2.75	1.63	1.50	
Organic matter	1	57.2 (5)	66.6 (4)	59.9 (6)	60.3 (2)	60.8 (3)	60.1 (1)	60.8
	2	58.7 (4)	66.8 (1)	62.2 (2)	60.3 (3)	60.8 (6)	59.9 (5)	61.5
	3	57.4 (2)	63.2 (3)	63.3 (4)	64.2 (5)	62.8 (1)	62.1 (6)	62.2
	4	61.0 (6)	67.8 (2)	63.6 (3)	63.7 (1)	63.2 (5)	61.7 (4)	63.5
	5	59.2 (1)	66.0 (6)	63.5 (5)	62.0 (4)	61.8 (2)	59.9 (3)	62.1
	6	57.4 (3)	68.8 (5)	64.3 (1)	63.7 (6)	62.9 (4)	60.7 (2)	63.0
	Mean	58.5	66.5	62.8	62.4	62.1	60.7	62.16
	S.E.	±0.60	±0.78	±0.64	±0.72	±0.44	±0.39	
	C.V.	2.52	2.87	2.51	2.83	1.74	1.58	
Nitrogen	1	58.5 (5)	53.9 (4)	62.1 (6)	57.3 (2)	58.9 (3)	54.8 (1)	57.6
	2	62.9 (4)	56.4 (1)	59.8 (2)	57.4 (3)	60.5 (6)	56.8 (5)	59.0
	3	56.6 (2)	54.0 (3)	60.4 (4)	58.9 (5)	56.6 (1)	60.5 (6)	57 8
	4	64.9 (6)	55.0 (2)	58.2 (3)	60.2 (1)	59.2 (5)	57.2 (4)	59.1
	5	56.4 (1)	51.7 (6)	57.2 (5)	53.2 (4)	57.1 (2)	58.5 (3)	55.7
	6	60.9 (3)	49.2 (5)	60.4 (1)	62.2 (6)	60.7 (4)	55.4 (2)	58.1
	Mean	60.0	53.4	59.7	58.2	58.8	57.2	57.89
	S.E.	±1.41	±1.04	±0.71	±1.25	±0.69	±0.85	
	C.V.	5.77	4.79	2.93	5.26	2.88	3.65	
Ether extract	1	54.3 (5)	77.2 (4)	66.7 (6)	63.9 (2)	66.2 (3)	63.1 (1)	65.2
	2	51.8 (4)	83.3 (1)	60.6 (2)	63.8 (3)	62.7 (6)	60.9 (5)	63.9
	3	51.6 (2)	84.6 (3)	58.3 (4)	59.2 (5)	64.0 (1)	64.0 (6)	63.6
	4	59.7 (6)	80.7 (2)	69.7 (3)	62.1 (1)	59.8 (5)	59.2 (4)	65.2
	5	52.9 (1)	80.1 (6)	59.2 (5)	57.0 (4)	61.3 (2)	64.8 (3)	62.6
	6	56.8 (3)	80.4 (5)	61.7 (1)	64.2 (6)	59.2 (4)	62.6 (2)	64.2
	Mean	54.5	81.1	62.7	61.7	62.2	62.4	64.10
	S.E.	±1.30	±1.06	±1.84	±1.21	±1.08	±0.84	
	C.V.	5.84	3.21	7.20	4.81	4.26	3.31	
Crude fibre	1	41.3 (5)	60.0 (4)	43.3 (6)	47.1 (2)	47.6 (3)	45.5 (1)	47.5
	2	40.9 (4)	57.9 (1)	50.8 (2)	47.5 (3)	45.0 (6)	46.8 (5)	48.2
	3	41.5 (2)	57.8 (3)	48.3 (4)	54.8 (5)	49.8 (1)	48.5 (6)	50.1
	4	41.4 (6)	62.0 (2)	54.5 (3)	50.2 (1)	53.2 (5)	45.8 (4)	51.2
	5	43.1 (1)	63.8 (6)	53.8 (5)	48.7 (4)	48.8 (2)	45.0 (3)	50.5
	6	40.1 (3)	70.0 (5)	51.9 (1)	49.7 (6)	48.3 (4)	46.4 (2)	51.1
	Mean	41.4	61.9	50.4	49.7	48.8	46.3	49.75
	S.E.	±0.40	±1.88	±1.69	±1.14	±1.10	±0.51	
	C.V.	2.38	7.42	8.20	5.61	5.54	2.67	

TABLE 8.—COEFFICIENTS OF DIGESTIBILITY OF TOTAL RATIONS ARRANGED BY ANIMALS AND BY LEVELS. EXPERIMENT 2—*Concluded*

(Coefficients in per cent, periods shown in brackets)

Nutrient	Animal	Hay	Silage	Mixed ration				Means
				Level I	Level II	Level III	Level IV	
N-free extract	1	67.6 (5)	70.9 (4)	69.9 (6)	68.9 (2)	69.5 (3)	70.0 (1)	69.5
	2	70.4 (4)	71.1 (1)	70.3 (2)	69.4 (3)	70.9 (6)	68.4 (5)	70.1
	3	69.0 (2)	65.8 (3)	73.2 (4)	71.4 (5)	71.9 (1)	71.1 (6)	70.4
	4	73.1 (6)	71.2 (2)	71.0 (3)	73.0 (1)	70.7 (5)	72.3 (4)	71.9
	5	70.7 (1)	68.1 (6)	71.7 (5)	72.1 (4)	70.8 (2)	69.7 (3)	70.5
	6	69.0 (3)	69.9 (5)	73.1 (1)	73.3 (6)	72.5 (4)	70.9 (2)	71.5
	Mean	70.0	69.5	71.5	71.4	71.1	70.4	70.63
	S.E.	±0.78	±0.88	±0.57	±0.75	±0.43	±0.55	
	C.V.	2.71	3.10	1.95	2.58	1.47	1.91	

TABLE 9.—MEAN COEFFICIENTS OF DIGESTIBILITY FOR EACH PERIOD (COEFFICIENTS IN PER CENT)

Nutrient	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6
Dry matter	61.0	60.0	59.5	60.9	61.2	60.7
Organic matter	62.8	61.7	60.9	62.5	62.8	62.3
Nitrogen	57.5	56.9	58.0	58.1	56.6	60.3
Ether extract	64.5	63.5	67.7	60.5	62.3	66.2
Crude fibre	49.7	49.4	48.8	48.7	53.3	48.6
N-free extract	71.6	70.2	69.1	71.9	70.0	71.1

From an examination of the data in Table 8, it will be observed that for the mixed ration there was a slight progressive drop in the digestibility of the dry matter, organic matter, nitrogen and crude fibre, as the level of feeding increased. In the case of ether extract, there was no change. In the case of the nitrogen-free extract, the coefficients for the hay alone, the silage alone, and for the mixed rations at all levels were very close together. There was, however, a slight drop in the digestibility of the mixed ration at the higher levels. From the table of necessary differences given in Table 11, it will be seen that the effect of the plane of nutrition upon the digestibility of the mixed ration was statistically significant for the dry matter, organic matter and the crude fibre, but not for the nitrogen, ether extract, or nitrogen-free extract.

The effect of the plane of nutrition upon the digestibility was much less marked in this experiment than in the previous one for the following reasons. It was shown in a previous paper (3) that the plane of nutrition had no effect upon the digestibility of hay. Further, in this experiment the silage only constituted a relatively small proportion of the total ration. If the coefficients of corn silage were calculated from the mixtures and arranged according to level, the differences would be magnified. This has been done and the results presented in Table 12. The errors, of course, were increased proportionately.

TABLE 10.—ANALYSIS OF VARIANCE OF COEFFICIENTS OF DIGESTIBILITY OF TOTAL RATIONS EXPERIMENT 2.

For $n_1 = 5$, $n_2 = 20$; Z at 0.05 = 0.4986; Z at 0.01 = 0.7058

Nutrient	Variance due to	D/F	Sums of squares	Variance	$\frac{1}{2} \log_e V$	Z to error
Dry matter	Ration	5	179.8830	35.9766	1.7919	1.7542
	Period	5	12.8442	2.5688	0.4717	0.4340
	Animal	5	25.3350	5.0670	0.8114	0.7737
	Error	20	21.5674	1.0784	0.0377	
	Total	35	239.6296			
Organic matter	Ration	5	210.9000	42.1800	1.8710	1.8304
	Period	5	17.1954	3.4391	0.6176	0.5770
	Animal	5	28.5576	5.7115	0.8713	0.8307
	Error	20	21.6926	1.0846	0.0406	
	Total	35	278.3456			
Nitrogen	Ration	5	178.0194	35.6039	1.7862	1.0199
	Period	5	52.4580	10.4916	1.1753	0.4090
	Animal	5	46.3242	9.2648	1.1131	0.3468
	Error	20	92.6020	4.6301	0.7663	
	Total	35	369.4036			
Ether extract	Ration	5	2359.1868	471.8374	3.0783	2.6164
	Period	5	205.8048	41.1610	1.8587	1.3968
	Animal	5	31.1088	6.2218	0.9140	0.4521
	Error	20	50.3796	2.5190	0.4619	
	Total	35	2646.4800			
Crude fibre	Ration	5	1387.6314	277.5263	2.8130	1.9761
	Period	5	97.7460	19.5492	1.4865	0.6496
	Animal	5	73.7460	14.7492	1.3456	0.5087
	Error	20	106.6466	5.3323	0.8269	
	Total	35	1665.7700			
N-free extract	Ration	5	19.6212	3.9242	0.6836	0.6085
	Period	5	35.4300	7.0860	0.9791	0.9040
	Animal	5	23.6880	4.7376	0.7778	0.7027
	Error	20	23.2412	1.1621	0.0751	
	Total	35	101.9804			

TABLE 11.—NECESSARY DIFFERENCES FOR SIGNIFICANCE IN MEAN COEFFICIENTS OF DIGESTIBILITY GIVEN IN TABLES 8 AND 9 ($P = 0.05$)

Nutrient	Necessary differences in absolute per cent	Nutrient	Necessary differences in absolute per cent
Dry matter	1.25	Ether extract	1.91
Organic matter	1.25	Crude fibre	2.78
Nitrogen	2.59	N-free extract	1.30

TABLE 12.—MEAN COEFFICIENTS OF DIGESTIBILITY OF CORN SILAGE CALCULATED FROM MIXTURES WITH HAY (COEFFICIENTS IN PER CENT, EACH VALUE THE AVERAGE OF SIX ANIMALS)

	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
Level I	74.0 ± 2.6	76.3 ± 2.7	58.4	81.9	83.2 ± 7.5	75.6 ± 2.1
Level II	72.3 ± 3.0	74.6 ± 3.1	49.0	78.3	79.7 ± 4.9	75.0 ± 2.7
Level III	71.1 ± 1.8	73.2 ± 2.0	53.3	79.9	75.7 ± 4.9	73.9 ± 1.5
Level IV	65.5 ± 1.6	67.9 ± 1.7	43.3	80.8	64.2 ± 2.2	71.4 ± 2.0

Experiment 3. Effect of the Plane of Nutrition upon the Digestibility of Corn Silage when Added to a Constant Ration of Hay

In Experiment 3 increasing quantities of corn silage were added to a basal ration of 4 kilogrammes of hay and the digestibility of the resulting rations determined. At the same time, the coefficients of digestibility of the hay alone and silage alone were determined. The corn silage was fed at levels of 5, 10, 16, 22, and *ad libitum* kilos per animal per day. The levels of corn silage were called I, II, III, IV, and V, respectively. These five mixtures together with the corn silage alone and the hay alone made 7 rations. Since at that time there were no facilities for conducting an experiment in a 7 × 7 randomized Latin square, a cyclic order of feeding was used. The schedule is shown in Table 13. It will be seen that each of the four animals used received each of the 7 rations once.

TABLE 13.—FEEDING SCHEDULE FOR EXPERIMENT 3

(Daily rations in kilogrammes; Roman numerals indicate level of feeding of corn silage when given with a basal ration of hay)

Period	Feed	Weights in kilogrammes							
		Animal 1		Animal 2		Animal 3		Animal 4	
1	Hay	4.0		4.0		4.0		4.0	
	Corn Silage	5.0	(I)	10.0	(II)	16.0	(III)	22.0	(IV)
2	Hay	4.0		7.5		0.0		4.0	
	Corn silage	25.91	(V)	0.0 –		22.0		5.0	(I)
3	Hay	4.0		4.0		4.0		4.0	
	Corn silage	10.0	(II)	16.0	(III)	22.0	(IV)	25.63	(V)
4	Hay	7.5		0.0		4.0		4.0	
	Corn silage	0.0		22.0		5.0	(I)	10.0	(II)
5	Hay	4.0		4.0		4.0		7.5	
	Corn silage	16.0	(III)	22.0	(IV)	27.88	(V)	0.0	
6	Hay	0.0		4.0		4.0		4.0	
	Corn silage	22.0		5.0	(I)	10.0	(II)	16.0	(III)
7	Hay	4.0		4.0		7.5		0.0	
	Corn silage	22.0	(IV)	26.08	(V)	0.0		22.0	

TABLE 14.—COEFFICIENTS OF DIGESTIBILITY OF HAY, CORN SILAGE FED ALONE, AND CORN SILAGE CALCULATED FROM MIXTURES WITH HAY. EXPERIMENT 3.

(Coeficients in per cent; Roman numerals indicate level of corn silage fed with the basal ration of hay.)

Animal No.	Hay alone	Corn silage alone	Corn silage calculated from mixed ration					
			Level I	Level II	Level III	Level IV	Level V	Means for Levels I – V
DRY MATTER								
1	50.2	67.4	72.6	70.8	66.8	61.6	65.9	67.5
2	51.3	66.2	71.1	72.8	67.6	66.4	65.3	68.6
3	52.5	68.1	68.7	67.4	67.8	65.4	64.7	66.8
4	51.8	67.4	78.6	65.6	67.1	67.0	64.7	68.6
Means	51.5	67.3	72.8	69.2	67.3	65.1	65.2	67.90
ORGANIC MATTER								
1	51.0	69.1	77.6	74.2	68.7	64.2	68.3	70.6
2	52.8	69.2	71.4	76.6	70.9	68.3	67.5	70.9
3	53.5	70.5	72.1	69.1	70.4	68.0	66.7	69.3
4	52.6	69.3	82.1	67.6	69.3	69.8	67.3	71.2
Means	52.5	69.5	75.8	71.9	69.8	67.6	67.5	70.51
NITROGEN								
1	58.4	57.8	33.3	49.4	52.3	51.7	42.6	45.9
2	57.0	49.6	52.4	38.5	42.8	50.2	53.7	47.5
3	60.6	51.8	54.3	54.0	36.5	48.5	51.5	49.0
4	59.1	60.0	53.6	45.7	53.5	36.5	42.5	46.4
Means	58.8	54.8	48.4	46.9	46.3	46.7	47.6	47.18
ETHER EXTRACT								
1	37.4	68.5	93.8	74.5	71.3	59.6	75.0	74.8
2	34.5	73.7	68.0	76.5	73.2	73.6	60.6	70.4
3	47.4	77.5	61.9	67.0	76.2	74.4	73.2	70.5
4	34.9	66.6	76.5	75.9	63.9	78.3	70.9	73.1
Means	38.6	71.6	75.1	73.5	71.2	71.5	69.9	72.22
CRUDE FIBRE								
1	39.3	62.8	76.2	77.6	67.5	56.9	68.0	69.2
2	44.7	66.5	70.5	75.7	71.6	62.5	63.5	68.8
3	41.2	67.4	69.7	65.3	62.3	64.0	60.5	64.4
4	42.1	62.3	105.4	63.5	68.5	65.0	65.5	73.6
Means	41.8	64.8	80.5	70.5	67.5	62.1	64.4	68.99
NITROGEN FREE EXTRACT								
1	59.0	74.0	80.8	75.8	71.5	70.0	71.7	74.0
2	59.8	72.8	76.1	80.0	73.6	73.3	72.1	75.0
3	62.8	73.6	76.8	73.4	76.3	71.7	71.5	73.9
4	61.0	74.7	75.5	71.6	72.8	74.6	70.9	73.1
Means	60.7	73.8	77.3	75.2	73.6	72.4	71.6	74.00

The experimental animals were numbered 1, 2, 3, and 4, with average weights for the entire experiment of, respectively, 562, 544, 568, and 525 kilogrammes. Animals 1, 2, and 3, were $3\frac{1}{2}$ years old at the commencement of the experiment, while Animal 4 was 2 years and 8 months.

The complete experimental data are given in Tables 23, 24, and 25, in the appendix. A summary of the coefficients of digestibility is given in Table 14. In this table are listed the coefficients of the digestibility of the hay alone, of the corn silage alone, and of the coefficients of the corn silage calculated from the mixtures with hay. In Table 15 is given an analysis of variance of the data in Table 14 for the calculated digestibilities of corn silage only.

TABLE 15.—ANALYSIS OF VARIANCE OF DATA IN TABLE 14
(For the 20 calculated values of silage only)
For $n_1 = 4$ and $n_2 = 12$, $z = 0.5907$ and 0.8443 for P of 0.05 and 0.01, respectively.

Nutrient	Variance due to	F	Sums of squares	Variance	$\frac{1}{2}\log_e V$	z compared with error
Dry matter	Plane	4	164.76	41.1900	1.8592	0.8457
	Animal	3	11.75	3.9167	0.6826	
	Error	12	91.10	7.5917	1.0135	
	Total	19	267.61			
Organic matter	Plane	4	191.79	47.9475	1.9351	0.6998
	Animal	3	10.50	3.5000	0.6264	
	Error	12	141.96	11.8300	1.2353	
	Total	19	344.25			
Crude fibre	Plane	4	822.08	205.52	2.6628	0.4996
	Animal	3	212.00	70.67	2.1290	
	Error	12	907.81	75.65	2.1632	
	Total	19	1941.89			
N-free extract	Plane	4	83.24	20.81	1.5177	0.6095
	Animal	3	9.10	3.03	0.5543	
	Error	12	73.80	6.15	0.9082	
	Total	19	166.14			

It will be observed from these data that in the case of dry matter, organic matter, crude fibre, and nitrogen-free extract, the digestibility of the corn silage decreased as the plane of nutrition increased. For the dry matter, organic matter and nitrogen-free extract, the decrease was statistically significant. In the case of the crude fibre, it was, however, not quite significant in spite of the big drop in digestibility. Two of the factors which contribute to this lack of significance are the large experimental error and the impossibility of eliminating the variance due to periods. The more important one is the rather large experimental error. This is particularly evident in the case of Animal 4 at Level I. It will be remembered that this was the ratio used in Experiment 2 where it was pointed out that the calculation of the coefficients of digestibility of corn

silage from a ration containing so little silage, resulted in the magnification of the errors.

In the case of the ether extract, there seemed to be a slight drop but it was not statistically significant. There was no effect of the plane of nutrition upon the digestibility of the nitrogen.

APPENDIX

TABLE 16.—CHEMICAL COMPOSITION OF CORN SILAGE IN PER CENT FOR EXPERIMENT 1

Period No.	Moisture	Nitrogen	On dry matter basis*				
			Ash	Protein**	Ether extract	Crude fibre	N-free extract
1	76.65	0.2960	5.55	7.50	2.69	24.74	59.52
2	75.07	0.3048	5.34	7.17	2.34	25.53	59.62
3	74.61	0.2993	5.47	6.84	2.28	25.16	60.25
4	79.58	0.2631	6.50	7.59	2.29	26.87	56.75
5	77.80	0.2701	6.58	7.40	2.57	26.42	57.03
6	76.67	0.2800	6.11	7.28	2.76	28.51	55.34

* Calculated from analysis of air-dried samples.
**N × 6.25.

TABLE 17.—CHEMICAL COMPOSITION OF REFUSED CORN SILAGE IN PER CENT FOR EXPERIMENT 1

Period No.	Animal No.	Moisture	Nitrogen	On dry matter basis*				
				Ash	Protein**	Ether extract	Crude fibre	N-free extract
1	4	73.55	0.3244	6.01	6.27	2.75	23.88	61.09
2	2	73.80	0.3210	7.01	7.10	2.60	28.33	54.96
2	5	74.66	0.2822	5.90	6.72	2.83	26.17	58.38
4	5	77.24	0.2897	6.75	7.44	2.43	26.04	57.34

* Calculated from analysis of air-dried samples.
** N × 6.25.

TABLE 18.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR EXPERIMENT 1
(Collection period of 12 days; weights in kilogrammes; coefficients in per cent)

—	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
PERIOD 1							
Animal 1							
In silage	312.000	72.852	68.809	0.924	1.960	18.024	43.362
In feces	124.803	23.972	21.131	0.406	0.412	7.470	11.008
Digested		48.880	47.678	0.518	1.548	10.554	32.354
Coefficient		67.1	69.3	56.1	79.0	58.6	74.6
Animal 2							
In silage	168.000	39.228	37.051	0.497	1.055	9.705	23.349
In feces	55.266	11.332	9.842	0.207	0.232	3.234	5.232
Digested		27.896	27.209	0.290	0.823	6.471	18.117
Coefficient		71.1	73.4	58.4	78.0	66.7	77.6

TABLE 18.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR EXPERIMENT 1—*Cont.*
(Collection period of 12 days; weights in kilogrammes; coefficients in per cent)

—	Original weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			PERIOD 1—*Concluded*				
Animal 3							
In silage	96.000	22.416	21.172	0.284	0.603	5.546	13.342
In feces	33.570	6.757	5.869	0.125	0.137	2.149	2.897
Digested		15.659	15.303	0.159	0.466	3.397	10.445
Coefficient		69.9	72.3	56.0	77.3	61.3	78.3
Animal 4							
In silage	384.000*	89.775	84.792	1.138	2.415	22.210	53.434
Refused	1.664	0.440	0.414	0.005	0.012	0.105	0.269
Consumed		89.335	84.378	1.133	2.403	22.105	53.165
In feces	229.644	34.482	30.682	0.506	0.521	11.551	15.741
Digested		54.853	53.696	0.627	1.882	10.554	37.424
Coefficient		61.4	63.6	55.3	78.3	47.7	70.4
Animal 5							
In silage	240.000	56.040	52.930	0.710	1.507	13.864	33.355
In feces	98.790	17.759	15.436	0.303	0.327	5.212	8.203
Digested		38.281	37.494	0.407	1.180	8.652	25.152
Coefficient		68.3	70.8	57.3	78.3	62.4	75.4
			PERIOD 2				
Animal 1							
In silage	96.000	23.933	22.655	0.293	0.560	6.110	14.269
In feces	34.481	6.803	5.963	0.134	0.133	2.065	3.013
Digested		17.130	16.692	0.159	0.427	4.045	11.256
Coefficient		71.6	73.7	54.3	76.3	66.2	78.9
Animal 2							
In silage	300.000	74.764	70.772	0.917	1.749	19.087	44.574
Refused	14.127	3.701	3.442	0.045	0.096	1.048	2.034
Consumed		71.063	67.330	0.872	1.653	18.039	42.540
In feces	182.428	27.056	24.304	0.392	0.384	9.516	12.113
Digested		44.007	43.026	0.480	1.269	8.523	30.427
Coefficient		61.9	63.9	55.0	76.8	47.2	71.5
Animal 3							
In silage	240.000	59.832	56.637	0.732	1.400	15.275	35.672
In feces	117.772	19.331	17.050	0.337	0.327	5.803	9.041
Digested		40.501	39.587	0.395	1.073	9.472	26.631
Coefficient		67.7	69.9	54.0	76.6	62.0	74.7
Animal 4							
In silage	168.000	41.882	39.646	0.512	0.980	10.692	24.970
In feces	77.727	12.955	11.402	0.218	0.225	3.736	6.190
Digested		28.927	28.244	0.294	0.755	6.956	18.780
Coefficient		69.1	71.2	57.4	77.0	65.1	75.2
Animal 5							
In silage	286.000	71.274	67.468	0.874	1.668	18.196	42.494
Refused	12.094	3.065	2.884	0.034	0.087	0.802	1.789
Consumed		68.209	64.584	0.840	1.581	17.394	40.705
In feces	174.321	26.935	24.153	0.381	0.391	8.894	12.668
Digested		41.274	40.431	0.459	1.190	8.500	28.037
Coefficient		60.5	62.6	54.6	75.3	48.9	68.9

* Original weights of corn silage in *ad libitum* feeding multiplied by corresponding percentage dry matter obtained from Table 16 will not give exactly the dry matter as shown. The dry matter in the corn silage consumed each day in excess of the constant ration was computed from the percentage dry matter in the corn silage for that day. The same is true for the nitrogen.

TABLE 18.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR EXPERIMENT 1—*Cont.*
(Collection period of 12 days; weights in kilogrammes; coefficients in per cent)

—	Original weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			PERIOD 3				
Animal 1							
In silage	96.000	24.374	23.041	0.287	0.556	6.132	14.685
In feces	34.713	6.993	6.115	0.137	0.139	1.930	3.252
Digested		17.381	16.926	0.150	0.417	4.202	11.433
Coefficient		71.3	73.5	52.3	75.0	68.5	77.9
Animal 2							
In silage	240.000	60.936	57.603	0.718	1.389	15.331	36.714
In feces	141.279	20.999	18.530	0.372	0.315	6.522	9.725
Digested		39.937	39.073	0.346	1.074	8.809	26.989
Coefficient		65.5	67.8	48.2	77.3	57.5	73.5
Animal 3							
In silage	291.000	73.906	69.863	0.869	1.685	18.595	44.528
In feces	186.308	26.575	23.585	0.417	0.375	8.493	12.280
Digested		47.331	46.278	0.452	1.310	10.102	32.248
Coefficient		64.0	66.2	52.0	77.7	54.3	72.4
Animal 4							
In silage	168.000	42.655	40.322	0.503	0.973	10.732	25.700
In feces	73.772	12.896	11.307	0.220	0.241	3.749	6.019
Digested		29.759	29.015	0.283	0.732	6.983	19.681
Coefficient		69.8	72.0	56.3	75.2	65.1	76.6
			PERIOD 4				
Animal 1							
In silage	252.000	51.388	48.048	0.663	1.177	13.808	29.163
In feces	92.213	17.550	14.940	0.299	0.263	5.063	7.834
Digested		33.838	33.108	0.364	0.914	8.745	21.329
Coefficient		65.8	68.9	54.9	77.7	63.3	73.1
Animal 2							
In silage	302.000	61.513	57.515	0.792	1.409	16.529	34.909
In feces	144.080	22.082	18.918	0.372	0.314	6.538	9.921
Digested		39.431	38.597	0.420	1.095	9.991	24.988
Coefficient		64.1	67.1	53.0	77.7	60.4	71.6
Animal 3							
In silage	180.000	36.686	34.301	0.474	0.840	9.858	20.819
In feces	82.205	11.700	9.972	0.255	0.191	3.256	5.064
Digested		24.986	24.329	0.219	0.649	6.602	15.755
Coefficient		68.1	70.9	46.2	77.3	67.0	75.7
Animal 4							
In silage	102.000	20.793	19.441	0.268	0.476	5.587	11.800
In feces	35.642	5.833	4.974	0.135	1.134	1.518	2.582
Digested		14.960	14.467	0.133	0.342	4.069	9.218
Coefficient		71.9	74.4	49.6	71.8	72.8	78.1
Animal 5							
In silage	322.000	65.688	61.418	0.845	1.504	17.650	37.278
Refused	4.369	0.994	0.927	0.013	0.024	0.259	0.570
Consumed		64.694	60.491	0.832	1.480	17.391	36.708
In feces	194.236	24.751	21.390	0.421	0.361	7.492	11.126
Digested		39.943	39.101	0.411	1.119	9.899	25.582
Coefficient		61.7	64.6	49.4	75.6	56.9	69.7

TABLE 18.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR EXPERIMENT 1—*Cont.*
(Collection period of 12 days; weights in kilogrammes; coefficients in per cent)

—	Original weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			PERIOD 5				
Animal 1							
In silage	314.000	69.640	65.058	0.848	1.790	18.399	39.716
In feces	165.831	26.950	22.924	0.414	0.396	8.225	11.850
Digested		42.690	42.134	0.434	1.394	10.174	27.866
Coefficient		61.3	64.8	51.2	77.9	55.3	70.2
Animal 2							
In silage	192.000	42.624	39.819	0.519	1.095	11.261	24.308
In feces	99.875	14.543	12.404	0.257	0.253	4.357	6.335
Digested		28.081	27.415	0.262	0.842	6.904	17.973
Coefficient		65.9	68.8	50.5	76.9	61.3	73.9
Animal 3							
In silage	108.000	23.976	22.398	0.292	0.616	6.334	13.674
In feces	40.411	7.080	6.221	0.150	0.125	2.164	3.059
Digested		16.896	16.177	0.142	0.491	4.170	10.615
Coefficient		70.5	72.2	48.6	79.7	65.8	77.6
Animal 4							
In silage	264.000	58.608	54.752	0.713	1.506	15.484	33.424
In feces	145.347	20.624	17.763	0.338	0.303	6.237	9.322
Digested		37.984	36.989	0.375	1.203	9.247	24.102
Coefficient		64.8	67.6	52.6	79.9	59.7	72.1
			PERIOD 6				
Animal 1							
In silage	180.000	41.994	39.428	0.504	1.159	11.972	23.239
In feces	85.316	14.901	12.766	0.259	0.253	4.415	6.595
Digested		27.093	26.662	0.245	0.906	7.557	16.644
Coefficient		64.5	67.6	48.6	78.2	63.1	71.6
Animal 2							
In silage	108.000	25.196	23.657	0.302	0.695	7.183	13.943
In feces	52.609	8.289	7.232	0.151	0.167	2.593	3.585
Digested		16.907	16.425	0.151	0.528	4.590	10.358
Coefficient		67.1	69.4	50.0	76.0	63.9	74.3
Animal 3							
In silage	252.000	58.792	55.200	0.706	1.623	16.762	32.535
In feces	152.447	21.591	18.458	0.376	0.343	6.363	9.597
Digested		37.201	36.742	0.330	1.280	10.399	22.938
Coefficient		63.3	66.6	46.7	78.9	62.0	70.5
Animal 4							
In silage	310.000	72.291	67.874	0.867	1.995	20.610	40.006
In feces	201.508	26.700	22.978	0.427	0.411	8.264	11.873
Digested		45.591	44.896	0.440	1.584	12.346	28.133
Coefficient		63.1	66.1	50.7	79.4	59.9	70.3

TABLE 19.—CHEMICAL COMPOSITION OF CORN SILAGE IN PER CENT FOR EXPERIMENT 2

Period No.	Moisture	Nitrogen	On dry matter basis*				
			Ash	Protein**	Ether extract	Crude fibre	N-free extract
1	78.14	0.2876	4.76	8.03	3.95	26.55	56.71
2	77.39	0.2947	5.24	8.22	3.34	27.34	55.86
3	77.28	0.3002	5.58	7.90	3.21	29.53	53.78
4	79.43	0.2807	4.64	8.47	3.11	26.47	57.31
5	79.54	0.2770	5.15	8.35	3.72	31.12	51.66
6	78.94	0.2844	4.50	8.46	3.61	30.27	53.16

* Calculated from analysis of air-dried samples.
** N × 6.25.

TABLE 20.—CHEMICAL COMPOSITION OF HAY IN PER CENT FOR EXPERIMENT 2

Period No.	Moisture	On dry matter basis				
		Ash	Protein**	Ether extract	Crude fibre	N-free extract
1	13.23	7.20	12.78	2.47	31.88	45.67
2	13.40	7.04	11.95	2.45	32.62	45.94
3	13.94	7.37	12.84	2.44	33.60	43.75
4	14.17	7.66	14.03	2.43	31.79	44.09
5	13.46	7.73	13.32	2.61	31.65	44.69
6	12.79	7.11	14.18	2.73	32.18	43.80

** N × 6.25.

TABLE 21.—BOTANICAL COMPOSITION OF HAY FOR EXPERIMENT 2

Species of herbage	Per cent	Species of herbage	Per cent
Alfalfa	39.2	Catch-fly	Trace
Red Clover	36.2	Kentucky blue grass	Trace
Alsike	7.2	Fowl blue grass	Trace
Timothy	14.7	Fleabane	Trace
Black medick	0.8	Dandelion	Trace
Couch grass	Trace	Stubble (mostly oats)	0.8
Red top	Trace		

TABLE 22.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR EXPERIMENT 2
(Collection period of 12 days; weights in kilogrammes; coefficients in per cent)

—	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
PERIOD 1							
Animal 1							
In hay	72.000	62.474	57.976	1.277	1.543	19.917	28.532
In silage	90.000	19.674	18.738	0.259	0.777	5.223	11.157
Total	162.000	82.148	76.714	1.536	2.320	25.140	39.689
In feces	184.654	34.262	30.572	0.695	0.857	13.705	11.906
Digested		47.886	46.142	0.841	1.463	11.435	27.783
Coefficient		58.3	60.1	54.8	63.1	45.5	70.0
Dig. from hay		35.735	33.916	0.766	0.841	8.246	19.972
Dig. from silage		12.151	12.226	0.075	0.622	3.189	7.811
Coeff. of silage		61.8	65.2	29.0	80.1	61.1	70.0

TABLE 22.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR EXPERIMENT 2—*Con.*
(Collection period of 12 days; weights in kilogrammes; coefficients in per cent)

—	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			PERIOD 1—*Concluded*				
Animal 2							
In silage	240.000	52.464	49.967	0.690	2.072	13.929	29.752
In feces	114.690	18.381	16.570	0.301	0.346	5.865	8.606
Digested		34.083	33.397	0.389	1.726	8.064	21.146
Coefficient		65.0	66.8	56.4	83.3	57.9	71.1
Animal 3							
In hay	60.000	52.062	48.314	1.064	1.286	16.597	23.777
In silage	75.000	16.395	15.615	0.216	0.648	4.353	9.298
Total	135.000	68.457	63.929	1.280	1.934	20.950	33.075
In feces	163.101	26.606	23.772	0.556	0.697	10.512	9.309
Digested		41.851	40.157	0.724	1.237	10.438	23.766
Coefficient		61.1	62.8	56.6	64.0	49.8	71.9
Dig. from hay		29.779	28.264	0.638	0.701	6.871	16.644
Dig. from silage		12.072	11.893	0.086	0.536	3.567	7.122
Coeff. of silage		73.6	76.2	39.8	82.7	81.9	76.6
Animal 4							
In hay	41.760	36.235	33 626	0.741	0.895	11.552	16.549
In silage	52.200	11.411	10.868	0.150	0.451	3.030	6.471
Total	93.960	47.646	44.494	0.891	1.346	14.582	23.020
In feces	104.936	18.142	16.148	0.355	0.510	7.268	6.210
Digested		29.504	28.346	0.536	0.836	7.314	16.810
Coefficient		61.9	63.7	60.2	62.1	50.2	73.0
Dig. from hay		20.726	19.671	0.445	0.488	4.783	11.584
Dig. from silage		8.778	8.675	0.091	0.348	2.531	5.226
Coeff. of silage		76.9	79.8	60.7	77.2	83.5	80.8
Animal 5							
In hay	84.000	72.887	67.639	1.490	1.800	23.236	33.287
In feces	189.390	30.916	27.596	0.649	0.847	13.226	9.769
Digested		41.971	40.043	0.841	0.953	10.010	23.518
Coefficient		57.6	59.2	56.4	52.9	43.1	70.7
Animal 6							
In hay	24.000	20.825	19.326	0.426	0.514	6.639	9.511
In silage	30.000	6.558	6.246	0.086	0.259	1.741	3.719
Total	54.000	27.383	25.572	0.512	0.773	8.380	13.230
In feces	41.440	10.316	9.129	0.203	0.296	4.033	3.556
Digested		17.067	16.443	0.309	0.477	4.347	9.674
Coefficient		62.3	64.3	60.4	61.7	51.9	73.1
Dig. from hay		11.912	11.306	0.256	0.280	2.749	6.658
Dig. from silage		5.155	5.137	0.053	0.197	1.598	3.016
Coeff. of silage		78.6	82.2	61.6	76.1	91.8	81.1
			PERIOD 2				
Animal 1							
In hay	41.760	36.164	33.618	0.691	0.886	11.797	16.614
In silage	52.200	11.802	11.184	0.154	0.394	3.227	6.593
Total	93.960	47.966	44.802	0.845	1.280	15.024	23.207
In feces	96.602	19.824	17.804	0.361	0.462	7.949	7.224
Digested		28.142	26.998	0.484	0.818	7.075	15.983
Coefficient		58.7	60.3	57.3	63.9	47.1	68.9
Dig. from hay		20.686	19.667	0.415	0.483	4.884	11.630
Dig. from silage		7.456	7.331	0.069	0.335	2.191	4.353
Coeff. of silage		63.2	65.5	44.8	85.0	67.9	66.0

TABLE 22.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR EXPERIMENT 2—*Cont.*
(Collection period of 12 days; weights in kilogrammes; coefficients in per cent)

—	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			PERIOD 2—*Concluded*				
Animal 2							
In hay	24.000	20.784	19.321	0.397	0.509	6.780	9.548
In silage	30 000	6.783	6.428	0.088	0.227	1.854	3.789
Total	54.000	27.567	25.749	0.485	0.736	8.634	13.337
In feces	57.711	10.920	9.735	0.195	0.290	4.245	3.955
Digested		16.647	16.014	0.290	0.446	4.389	9.382
Coefficient		60.4	62.2	59.8	60.6	50.8	70.3
Dig. from hay		11.888	11.303	0.238	0.277	2.807	6.684
Dig. from silage		4.759	4.711	0.052	0.169	1.582	2.698
Coeff. of silage		70.2	73.3	59.1	74.4	85.3	71.2
Animal 3							
In hay	84.000	72.744	67.623	1.391	1.782	23.729	33.419
In feces	169.267	31.931	28.792	0.604	0.862	13.893	10.371
Digested		40.813	38.831	0.787	0.920	9.836	23.048
Coefficient		56.1	57.4	56.6	51.6	41.5	69.0
Animal 4							
In silage	240.000	54.264	51.421	0.707	1.812	14.836	30.312
In feces	113.888	18.642	16.582	0.318	0.350	5.634	8.732
Digested		35.622	34.839	0.389	1.462	9.202	21.580
Coefficient		65.6	67.8	55.0	80.7	62.0	71.2
Animal 5							
In hay	60.000	51.960	48.302	0.993	1.273	16.949	23.870
In silage	75.000	16.958	16.069	0.221	0.566	4.636	9.473
Total	135.000	68.918	64.371	1.214	1.839	21.585	33.343
In feces	151.747	27.395	24.620	0.521	0.712	11.059	9.722
Digested		41.523	39.751	0.693	1.127	10.526	23.621
Coefficient		60.2	61.8	57.1	61.3	48.8	70.8
Dig. from hay		29.721	28.257	0.596	0.694	7.017	16.709
Dig. from silage		11.802	11.494	0.097	0.433	3.509	6.912
Coeff. of silage		69.6	71.5	43.9	76.5	75.7	73.0
Animal 6							
In hay	72.000	62.352	57.962	1.192	1.528	20.339	28.645
In silage	90.000	20.349	19.283	0.265	0.680	5.563	11.367
Total	162.000	82.701	77.245	1.457	2.208	25.902	40.012
In feces	192.357	33.810	30.328	0.650	0.825	13.889	11.654
Digested		48.891	46.917	0.807	1.383	12.013	28.358
Coefficient		59.1	60.7	55.4	62.6	46.4	70.9
Dig. from hay		35.665	33.908	0.715	0.833	8.420	20.052
Dig. from silage		13.226	13.009	0.092	0.550	3.593	8.306
Coeff. of silage		65.0	67.5	34.7	80.9	64.6	73.1
			PERIOD 3				
Animal 1							
In hay	60.000	51.636	47.830	1.061	1.260	17.350	22.591
In silage	75.000	17.040	16.089	0.225	0.547	5.032	9.164
Total	135.000	68.676	63.919	1.286	1.807	22.382	31.755
In feces	143.923	27.772	25.073	0.528	0.611	11.725	9.670
Digested		40.904	38.846	0.758	1.196	10.657	22.085
Coefficient		59.6	60.8	58.9	66.2	47.6	69.5
Dig. from hay		29.536	27.981	0.637	0.687	7.183	15.814
Dig. from silage		11.368	10.865	0.121	0.509	3.474	6.271
Coeff. of silage		66.7	67.5	53.8	93.1	69.0	68.4

TABLE 22.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR EXPERIMENT 2—*Cont.*
(Collection period of 12 days; weights in kilogrammes; coefficients in per cent)

—	Original weight	Dry matter	Organic matter	Nitrogen	Ether Extract	Crude fibre	N-free Extract
			PERIOD 3—*Concluded*				
Animal 2							
In hay	41.760	35.939	33.290	0.738	0.877	12.076	15.723
In silage	52.200	11.860	11.198	0.157	0.381	3.502	6.378
Total	93.960	47.799	44.488	0.895	1.258	15.578	22.101
In feces	144.866	19.628	17.640	0.381	0.455	8.177	6.772
Digested		28.171	26.848	0.514	0.803	7.401	15.329
Coefficient		58.9	60.3	57.4	63.8	47.5	69.4
Dig. from hay		20.557	19.475	0.443	0.478	4.999	11.006
Dig. from silage		7.614	7.373	0.071	0.325	2.402	4.323
Coeff. of silage		64.2	65.8	45.2	85.3	68.6	67.8
Animal 3							
In silage	240.000	54.528	51.485	0.720	1.750	16.102	29.325
In feces	126.830	21.086	18.954	0.331	0.270	6.796	10.031
Digested		33.442	32.531	0.389	1.480	9.306	19.294
Coefficient		61.3	63.2	54.0	84.6	57.8	65.8
Animal 4							
In hay	24.000	20.654	19.132	0.424	0.504	6.940	9.036
In silage	30.000	6.816	6.436	0.090	0.219	2.013	3.666
Total	54.000	27.470	25.568	0.514	0.723	8.953	12.702
In feces	53.791	10.439	9.294	0.215	0.219	4.076	3.684
Digested		17.031	16.274	0.299	0.504	4.877	9.018
Coefficient		62.0	63.6	58.2	69.7	54.5	71.0
Dig. from hay		11.814	11.192	0.254	0.275	2.873	6.325
Dig. from silage		5.217	5.082	0.045	0.229	2.004	2.693
Coeff. of silage		76.5	79.0	50.0	104.6	99.6	73.5
Animal 5							
In hay	72.000	61.963	57.396	1.273	1.512	20.820	27.109
In silage	90.000	20.448	19.307	0.270	0.656	6.038	10.997
Total	162.000	82.411	76.703	1.543	2.168	26.858	38.106
In feces	205.151	33.975	30.751	0.640	0.764	14.772	11.535
Digested		48.436	45.952	0.903	1.404	12.086	26.571
Coefficient		58.8	59.9	58.5	64.8	45.0	69.7
Dig. from hay		35.443	33.577	0.764	0.824	8.619	18.976
Dig. from silage		12.993	12.375	0.139	0.580	3.467	7.595
Coeff. of silage		63.5	64.1	51.5	88.4	57.4	69.1
Animal 6							
In hay	84.000	72.290	66.962	1.485	1.764	24.289	31.627
In feces	164.072	31.491	28.553	0.580	0.762	14.546	9.797
Digested		40.799	38.409	0.905	1.002	9.743	21.830
Coefficient		56.4	57.4	60.9	56.8	40.1	69.0
			PERIOD 4				
Animal 1							
In silage	240.000	49.368	47.077	0.674	1.535	13.068	28.293
In feces	90.675	17.596	15.738	0.311	0.350	5.233	8.238
Digested		31.772	31.339	0.363	1.185	7.835	20.055
Coefficient		64.4	66.6	53.9	77.2	60.0	70.9
Animal 2							
In hay	84.000	72.097	66.574	1.619	1.752	22.920	31.788
In feces	207.830	30.799	27.470	0.601	0.844	13.539	9.406
Digested		41.298	39.104	1.018	0.908	9.381	22.382
Coefficient		57.3	58.7	62.9	51.8	40.9	70.4

TABLE 22.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR EXPERIMENT 2—*Cont.*
(Collection period of 12 days; weights in kilogrammes; coefficients in per cent)

—	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			PERIOD 4—*Concluded*				
Animal 3							
In hay	24.000	20.599	19.021	0.462	0.501	6.548	9.082
In silage	30.000	6.171	5.885	0.084	0.192	1.633	3.537
Total	54.000	26.770	24.906	0.546	0.693	8.181	12.619
In feces	45.130	10.199	9.137	0.216	0.289	4.233	3.381
Digested		16.571	15.769	0.330	0.404	3.948	9.238
Coefficient		61.9	63.3	60.4	58.3	48.3	73.2
Dig. from hay		11.783	11.127	0.277	0.273	2.711	6.357
Dig. from silage		4.788	4.642	0.053	0.131	1.237	2.881
Coeff. of silage		77.6	78.9	63.1	68.2	75.8	81.5
Animal 4							
In hay	72.000	61.798	57.064	1.387	1.502	19.646	27.247
In silage	90.000	18.513	17.654	0.253	0.576	4.900	10.610
Total	162.000	80.311	74.718	1.640	2.078	24.546	37.857
In feces	202.584	32.209	28.631	0.702	0.847	13.309	10.490
Digested		48.102	46.087	0.938	1.231	11.237	27.367
Coefficient		59.9	61.7	57.2	59.2	45.8	72.3
Dig. from hay		35.348	33.382	0.832	0.819	8.133	19.073
Dig. from silage		12.754	12.705	0.106	0.412	3.104	8.294
Coeff. of silage		68.9	72.0	41.9	71.5	63.3	78.2
Animal 5							
In hay	41.760	35.843	33.097	0.805	0.871	11.394	15.803
In silage	52.200	10.738	10.240	0.147	0.334	2.842	6.154
Total	93.960	46.581	43.337	0.952	1.205	14.236	21.957
In feces	130.359	18.497	16.464	0.446	0.518	7.303	6.128
Digested		28.084	26.873	0.506	0.687	6.933	15.829
Coefficient		60.3	62.0	63.2	57.0	48.7	72.1
Dig. from hay		20.502	19.362	0.483	0.475	4.717	11.062
Dig. from silage		7.582	7.511	0.023	0.212	2.216	4.767
Coeff. of silage		70.6	73.3	15.6	63.5	78.0	77.5
Animal 6							
In hay	60.000	51.498	47.553	1.156	1.251	16.371	22.705
In silage	75.000	15.428	14.712	0.211	0.480	4.084	8.842
Total	135.000	66.926	62.265	1.367	1.731	20.455	31.547
In feces	141.805	25.894	23.090	0.537	0.707	10.570	8.664
Digested		41.032	39.175	0.830	1.024	9.885	22.883
Coefficient		61.3	62.9	60.7	59.2	48.3	72.5
Dig. from hay		29.457	27.819	0.694	0.682	6.778	15.894
Dig. from silage		11.575	11.356	0.136	0.342	3.107	6.989
Coeff. of silage		75.0	77.2	64.5	71.3	76.1	79.0
			PERIOD 5				
Animal 1							
In hay	84.000	72.694	67.075	1.550	1.897	23.008	32.487
In feces	158.580	31.889	28.675	0.644	0.867	13.505	10.536
Digested		40.805	38.400	0.906	1.030	9.503	21.951
Coefficient		56.1	57.2	58.5	54.3	41.3	67.6
Animal 2							
In hay	81.000	70.097	64.679	1.494	1.830	22.186	31.326
In silage	101.250	20.716	19.649	0.280	0.771	6.447	10.702
Total	182.250	90.813	84.328	1.774	2.601	28.633	42.028
In feces	268.370	37.848	33.810	0.767	1.018	15.230	13.277
Digested		52.965	50.518	1.007	1.583	13.403	28.751
Coefficient		58.3	59.9	56.8	60.9	46.8	68.4
Dig. from hay		40.095	37.837	0.896	0.997	9.185	21.928
Dig. from silage		12.870	12.681	0.111	0.586	4.218	6.823
Coeff. of silage		62.1	64.5	39.6	76.0	65.4	63.8

TABLE 22.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR EXPERIMENT 2—*Cont.*
(Collection period of 12 days; weights in kilogrammes; coefficients in per cent)

—	Original weight	Dry matter	Organic matter	Nitrogen	Ether Extract	Crude fibre	N-free extract
			PERIOD 5—*Concluded*				
Animal 3							
In hay	41.760	36.139	33.345	0.770	0.943	11.438	16.151
In silage	52.200	10.680	10.130	0.145	0.397	3.324	5.517
Total	93.960	46.819	43.475	0.915	1.340	14.762	21.668
In feces	82.269	17.590	15.581	0.376	0.547	6.670	6.195
Digested		29.229	27.894	0.539	0.793	8.092	15.473
Coefficient		62.4	64.2	58.9	59.2	54.8	71.4
Dig. from hay		20.672	19.507	0.462	0.514	4.735	11.306
Dig. from silage		8.557	8.387	0.077	0.279	3.357	4.167
Coeff. of silage		80.1	82.8	53.1	70.3	101.0	75.5
Animal 4							
In hay	60.000	51.924	47.910	1.107	1.355	16.434	23.205
In silage	75.000	15.345	14.555	0.208	0.571	4.775	7.927
Total	135.000	67.269	62.465	1.315	1.926	21.209	31.132
In feces	163.775	25.904	23.018	0.537	0.775	9.934	9.116
Digested		41.365	39.447	0.778	1.151	11.275	22.016
Coefficient		61.5	63.2	59.2	59.8	53.2	70.7
Dig. from hay		29.701	28.027	0.664	0.738	6.804	16.244
Dig. from silage		11.664	11.420	0.114	0.413	4.471	5.772
Coeff. of silage		76.0	78.5	54.8	72.3	93.6	72.8
Animal 5							
In hay	24.000	20.770	19.164	0.443	0.542	6.574	9.282
In silage	30.000	6.138	5.822	0.083	0.228	1.910	3.171
Total	54.000	26.908	24.986	0.526	0.770	8.484	12.453
In feces	64.566	10.228	9.110	0.225	0.314	3.916	3.518
Digested		16.680	15.876	0.301	0.456	4.568	8.935
Coefficient		62.0	63.5	57.2	59.2	53.8	71.7
Dig. from hay		11.880	11.211	0.266	0.295	2.722	6.497
Dig. from silage		4.800	4.665	0.035	0.161	1.846	2.438
Coeff. of silage		78.2	80.1	42.2	70.6	96.6	76.9
Animal 6							
In silage	240.000	49.104	46.575	0.665	1.827	15.281	25.367
In feces	118.304	16.265	14.543	0.338	0.359	4.588	7.623
Digested		32.839	32.032	0.327	1.468	10.693	17.744
Coefficient		66.9	68.8	49.2	80.4	70.0	69.9
			PERIOD 6				
Animal 1							
In hay	24.000	20.930	19.442	0.475	0.571	6.735	9.167
In silage	30.000	6.318	6.034	0.085	0.228	1.912	3.359
Total	54.000	27.248	25.476	0.560	0.799	8.647	12.526
In feces	46.826	11.314	10.220	0.212	0.266	4.899	3.773
Digested		15.934	15.256	0.348	0.533	3.748	8.753
Coefficient		58.5	59.9	62.1	66.7	43.3	69.9
Dig. from hay		11.972	11.374	0.285	0.311	2.788	6.417
Dig. from silage		3.962	3.882	0.063	0.222	0.960	2.336
Coeff. of silage		62.7	64.3	74.1	97.4	50.2	69.5
Animal 2							
In hay	60.000	52.326	48.606	1.188	1.428	16.839	22.919
In silage	75.000	15.795	15.084	0.213	0.570	4.781	8.397
Total	135.000	68.121	63.690	1.401	1.998	21.620	31.316
In feces	184.066	27.830	24.983	0.554	0.746	11.881	9.100
Digested		40.291	38.707	0.847	1.252	9.739	22.216
Coefficient		59.1	60.8	60.5	62.7	45.0	70.9
Dig. from hay		29.930	28.435	0.713	0.778	6.971	16.043
Dig. from silage		10.361	10.272	0.134	0.474	2.768	6.173
Coeff. of silage		65.6	68.1	62.9	83.2	57.9	73.5

TABLE 22.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR EXPERIMENT 2—*Conc.*
(Collection period of 12 days; weights in kilogrammes; coefficients in per cent)

—	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			PERIOD 6—*Concluded*				
Animal 3							
In hay	81.000	70.640	65.617	1.604	1.928	22.732	30.940
In silage	101.250	21.323	20.363	0.288	0.770	6.454	11.335
Total	182.250	91.963	85.980	1.892	2.698	29.186	42.275
In feces	204.308	36.336	32.553	0.748	0.970	15.043	12.198
Digested		55.627	53.427	1.144	1.728	14.143	30.077
Coefficient		60.5	62.1	60.5	64.0	48.5	71.1
Dig. from hay		40.406	38.386	0.962	1.051	9.411	21.658
Dig. from silage		15.221	15.041	0.182	0.677	4.732	8.419
Coeff. of silage		71.4	73.9	63.2	87.9	73.3	74.3
Animal 4							
In hay	84.000	73.256	68.047	1.663	2.000	23.574	32.086
In feces	168.303	29.687	26.555	0.583	0.807	13.819	8.630
Digested		43.569	41.492	1.080	1.193	9.755	23.456
Coefficient		59.5	61.0	64.9	59.7	41.4	73.1
Animal 5							
In silage	240.000	50.544	48.270	0.683	1.825	15.300	26.869
In feces	133.824	18.070	16.389	0.330	0.363	5.531	8.580
Digested		32.474	31.881	0.353	1.462	9.769	18.289
Coefficient		64.2	66.0	51.7	80.1	63.8	68.1
Animal 6							
In hay	41.760	36.419	33.830	0.827	0.994	11.720	15.952
In silage	52.200	10.993	10.498	0.148	0.397	3.328	5.844
Total	93.960	47.412	44.328	0.975	1.391	15.048	21.796
In feces	97.600	17.924	16.094	0.369	0.498	7.564	5.827
Digested		29.488	28.234	0.606	0.893	7.484	15.969
Coefficient		62.2	63.7	62.2	64.2	49.7	73.3
Dig. from hay		20.832	19.791	0.496	0.542	4.852	11.166
Dig. from silage		8.656	8.443	0.110	0.351	2.632	4.803
Coeff. of silage		78.7	80.4	74.3	88.4	79.1	82.2

TABLE 23. CHEMICAL COMPOSITION OF HAY FOR EXPERIMENT 3 IN PER CENT

Period No.	Moisture	On dry matter basis				
		Ash	Protein*	Ether extract	Crude fibre	N-free extract
1	13.17	7.09	12.66	2.04	36.15	42.06
2	13.95	7.54	12.14	1.74	38.84	39.74
3	14.05	8.14	12.68	1.99	36.52	40.67
4	13.14	7.71	12.46	1.82	37.14	40.87
5	13.19	7.81	12.07	1.91	37.59	40.62
6	12.31	7.75	12.00	1.79	38.25	40.21
7	12.21	7.42	12.57	1.89	37.57	40.55

*N × 6.25.

TABLE 24. CHEMICAL COMPOSITION OF CORN SILAGE FOR EXPERIMENT 3 IN PER CENT

Period No.	Moisture	On dry matter basis				
		Ash	Protein*	Ether extract	Crude fibre	N-free extract
1	76.07	6.06	6.78	2.36	25.06	59.74
2	76.70	7.40	7.44	2.90	26.49	55.77
3	76.31	7.15	7.78	2.54	25.48	57.05
4	76.54	6.97	8.18	2.48	26.44	55.93
5	75.86	6.70	9.27	2.59	25.78	55.66
6	76.26	6.09	9.97	2.83	27.94	53.17
7	75.09	6.91	11.02	2.58	27.50	51.99

* N × 6.25.

TABLE 25.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR EXPERIMENT 3
(Collection period of 12 days; weights in kilogrammes; coefficients in per cent)

—	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			PERIOD 1				
Animal No. 1							
In hay	48.000	41.678	38.723	0.844	0.850	15.067	17.530
In silage	60.000	14.358	13.488	0.156	0.339	3.598	8.577
Total	108.000	56.036	52.211	1.000	1.189	18.665	26.107
In feces	122.858	24.151	21.420	0.452	0.543	9.624	8.537
Digested		31.885	30.791	0.548	0.646	9.041	17.570
Coefficient		56.9	59.0	54.8	54.3	48.4	67.3
Dig. from hay		21.464	20.330	0.496	0.328	6.298	10.641
Dig. from silage		10.421	10.461	0.052	0.318	2.743	6.929
Coeff. of silage		72.6	77.6	33.3	93.8	76.2	80.8
Animal No. 2							
In hay	48.000	41.678	38.723	0.844	0.850	15.067	17.530
In silage	120.000	28.716	26.976	0.312	0.678	7.196	17.155
Total	168.000	70.394	65.699	1.156	1.528	22.263	34.685
In feces	170.409	28.035	24.707	0.540	0.681	10.519	10.314
Digested		42.359	40.992	0.616	0.847	11.744	24.371
Coefficient		60.2	62.4	53.3	55.4	52.8	70.3
Dig. from hay		21.464	20.330	0.496	0.328	6.298	10.641
Dig. from silage		20.895	20.662	0.120	0.519	5.446	13.730
Coeff. of silage		72.8	76.6	38.5	76.5	75.7	80.0
Animal No. 3							
In hay	48.000	41.678	38.723	0.844	0.850	15.067	17.530
In silage	192.000	45.946	43.162	0.498	1.084	11.514	27.448
Total	240.000	87.624	81.885	1.342	1.934	26.581	44.978
In feces	199.447	34.998	31.162	0.664	0.780	13.114	13.390
Digested		52.626	50.723	0.678	1.154	13.467	31.588
Coefficient		60.1	61.9	50.5	59.7	50.7	70.2
Dig. from hay		21.464	20.330	0.496	0.328	6.298	10.641
Dig. from silage		31.162	30.393	0.182	0.826	7.169	20.947
Coeff. of silage		67.8	70.4	36.5	76.2	62.3	76.3
Animal No. 4							
In hay	48.000	41.678	38.723	0.844	0.850	15.067	17.530
In silage	264.000	63.175	59.347	0.685	1.491	15.832	37.741
Total	312.000	104.853	98.070	1.529	2.341	30.899	55.271
In feces	307.255	41.090	36.291	0.783	0.846	14.308	16.465
Digested		63.763	61.779	0.746	1.495	16.591	38.806
Coefficient		60.8	63.0	48.8	63.9	53.7	70.2
Dig. from hay		21.464	20.330	0.496	0.328	6.298	10.641
Dig. from silage		42.299	41.449	0.250	1.167	10.293	28.165
Coeff. of silage		67.0	69.8	36.5	78.3	65.0	74.6

TABLE 25.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR EXPERIMENT 3—*Cont.*
(Collection period of 12 days; weights in kilogrammes; coefficients in per cent)

—	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			PERIOD 2				
*Animal No. 1**							
In hay	64.000	55.072	50.920	1.070	0.958	21.390	21.886
In silage	414.551	96.590	89.442	1.150	2.801	25.587	53.868
Total	478.551	151.662	140.362	2.220	3.759	46.977	75.754
In feces	381.627	59.642	52.557	1.101	1.288	20.636	23.863
Digested		92.020	87.805	1.119	2.471	26.341	51.891
Coefficient		60.7	62.6	50.4	65.7	56.1	68.5
Dig. from hay		28.362	26.733	0.629	0.370	8.941	13.285
Dig. from silage		63.658	61.072	0.490	2.101	17.400	38.606
Coeff. of silage		65.9	68.3	42.6	75.0	68.0	71.7
Animal No. 2							
In hay	90.000	77.445	71.606	1.504	1.348	30.080	30.777
In feces	225.357	37.721	33.787	0.646	0.883	16.635	12.380
Digested		39.724	37.819	0.858	0.465	13.445	18.397
Coefficient		51.3	52.8	57.0	34.5	44.7	59.8
Animal No. 3							
In silage	264.000	61.512	56.960	0.733	1.784	16.295	34.305
In feces	123.779	19.602	16.779	0.353	0.402	5.320	9.050
Digested		41.910	40.181	0.380	1.382	10.975	25.255
Coefficient		68.1	70.5	51.8	77.5	67.4	73.6
Animal No. 4							
In hay	48.000	41.304	38.190	0.802	0.719	16.042	16.414
In silage	60.000	13.980	12.945	0.166	0.405	3.703	7.797
Total	108.000	55.284	51.135	0.968	1.124	19.745	24.211
In feces	135.093	23.021	20.463	0.407	0.536	9.135	8.361
Digested		32.263	30.672	0.561	0.588	10.610	15.850
Coefficient		58.4	60.0	58.0	52.3	53.7	65.5
Dig. from hay		21.272	20.050	0.472	0.278	6.706	9.963
Dig. from silage		10.991	10.622	0.089	0.310	3.904	5.887
Coeff. of silage		78.6	82.1	53.6	76.5	105.4	75.5
			PERIOD 3				
Animal No. 1							
In hay	48.000	41.256	37.898	0.837	0.821	15.067	16.779
In silage	120.000	28.428	26.395	0.354	0.722	7.243	16.218
Total	168.000	69.684	64.293	1.191	1.543	22.310	32.997
In feces	142.265	28.312	24.815	0.524	0.688	10.388	10.524
Digested		41.372	39.478	0.667	0.855	11.922	22.473
Coefficient		59.4	61.4	56.0	55.4	53.4	68.1
Dig. from hay		21.247	19.896	0.492	0.317	6.298	10.185
Dig. from silage		20.125	19.582	0.175	0.538	5.624	12.288
Coeff. of silage		70.8	74.2	49.4	74.5	77.6	75.8
Animal No. 2							
In hay	48.000	41.256	37.898	0.837	0.821	15.067	16.779
In silage	192.000	45.485	42.232	0.566	1.155	11.590	25.949
Total	240.000	86.741	80.130	1.403	1.976	26.657	42.728
In feces	242.251	34.765	30.312	0.669	0.814	12.060	13.451
Digested		51.976	49.818	0.734	1.162	14.597	29.277
Coefficient		59.9	62.2	52.3	58.8	54.8	68.5
Dig. from hay		21.247	19.896	0.492	0.317	6.298	10.185
Dig. from silage		30.729	29.922	0.242	0.845	8.299	19.092
Coeff. of silage		67.6	70.9	42.8	73.2	71.6	73.6

* Collection period of 16 days.

TABLE 25.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR EXPERIMENT 3—*Cont.*
(Collection period of 12 days; weights in kilogrammes; coefficients in per cent)

—	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			PERIOD 3—*Concluded*				
Animal No. 3							
In hay	48.000	41.256	37.898	0.837	0.821	15.067	16.779
In silage	264.000	62.542	58.163	0.779	1.591	15.961	35.737
Total	312.000	103.798	96.061	1.616	2.412	31.028	52.516
In feces	238.754	41.654	36.631	0.746	0.912	14.512	16.712
Digested		62.144	59.430	0.870	1.500	16.516	35.804
Coefficient		59.9	61.9	53.8	62.2	53.2	68.2
Dig. from hay		21.247	19.896	0.492	0.317	6.298	10.185
Dig. from silage		40.897	39.534	0.378	1.183	10.218	25.619
Coeff. of silage		65.4	68.0	48.5	74.4	64.0	71.7
*Animal No. 4**							
In hay	64.000	55.008	50.530	1.116	1.095	20.089	22.372
In silage	410.000	97.129	90.184	1.209	2.467	24.740	55.412
Total	474.000	152.137	140.714	2.325	3.562	44.837	77.784
In feces	421.457	60.950	53.478	1.155	1.390	20.241	24.892
Digested		91.187	87.236	1.170	2.172	24.596	52.892
Coefficient		59.9	62.0	50.3	61.0	54.9	68.0
Dig. from hay		28.329	26.528	0.656	0.423	8.397	13.580
Dig. from silage		62.858	60.708	0.514	1.749	16.199	39.312
Coeff. of silage		64.7	67.3	42.5	70.9	65.5	70.9
			PERIOD 4				
Animal No. 1							
In hay	90.000	78.174	72.147	1.558	1.423	29.034	31.950
In feces	206.150	38.900	35.387	0.648	0.891	17.614	13.090
Digested		39.274	36.760	0.910	0.532	11.420	18.860
Coefficient		50.2	51.0	58.4	37.4	39.3	59.0
Animal No. 2							
In silage	264.000	61.934	57.617	0.811	1.536	16.375	34.640
In feces	153.484	20.932	17.738	0.409	0.404	5.480	9.419
Digested		41.002	39.879	0.402	1.132	10.895	25.221
Coefficient		66.2	69.2	49.6	73.7	66.5	72.8
Animal No. 3							
In hay	48.000	41.693	38.478	0.831	0.759	15.485	17.040
In silage	60.000	14.076	13.095	0.184	0.349	3.722	7.873
Total	108.000	55.769	51.573	1.015	1.108	19.207	24.913
In feces	121.114	24.633	21.936	0.426	0.599	10.141	8.521
Digested		31.136	29.637	0.589	0.509	9.066	16.392
Coefficient		55.8	57.5	58.0	45.9	47.2	65.8
Dig. from hay		21.472	20.201	0.489	0.293	6.473	10.342
Dig. from silage		9.664	9.436	0.100	0.216	2.593	6.049
Coeff. of silage		68.7	72.1	54.3	61.9	69.7	76.8
Animal No. 4							
In hay	48.000	41.693	38.478	0.831	0.759	15.485	17.040
In silage	120.000	28.152	26.190	0.368	0.698	7.443	15.745
Total	168.000	69.845	64.668	1.198	1.457	22.928	13.785
In feces	183.117	29.898	26.753	0.542	0.634	11.732	11.173
Digested		39.947	37.915	0.657	0.823	11.196	21.612
Coefficient		57.2	58.6	54.8	56.5	48.8.	65.9
Dig. from hay		21.472	20.201	0.489	0.293	6.473	10.343
Dig. from silage		18.475	17.714	0.168	0.530	4.723	11.269
Coeff. of silage		65.6	67.6	45.7	75.9	63.5	71.6

* Collection period of 16 days.

TABLE 25.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR EXPERIMENT 3.—*Cont.*
(Collection period of 12 days; weights in kilogrammes; coefficients in per cent)

	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
PERIOD 5							
Animal No. 1							
In hay	48.000	41.669	38.415	0.805	0.796	15.663	16.926
In silage	192.000	46.349	43.244	0.688	1.200	11.949	25.798
Total	240.000	88.018	81.659	1.493	1.996	27.612	42.724
In feces	205.955	35.592	31.777	0.660	0.833	13.005	13.995
Digested		52.426	49.882	0.833	1.163	14.607	28.729
Coefficient		59.6	61.1	55.8	58.3	52.9	67.2
Dig. from hay		21.460	20.168	0.473	0.307	6.547	10.274
Dig. from silage		30.966	29.714	0.360	0.856	8.060	18.455
Coeff. of silage		66.8	68.7	52.3	71.3	67.5	71.5
Animal No. 2							
In hay	47.924	41.603	38.354	0.804	0.795	15.639	16.899
In silage	264.000	63.730	59.460	0.946	1.651	16.430	35.472
Total	311.924	105.333	97.814	1.750	2.446	32.069	52.371
In feces	292.644	41.600	37.074	0.802	0.924	15.267	16.108
Digested		63.733	60.740	0.948	1.522	16.802	36.263
Coefficient		60.5	62.1	54.2	62.2	52.4	69.2
Dig. from hay		21.426	20.136	0.473	0.307	6.537	10.258
Dig. from silage		42.307	40.604	0.475	1.215	10.265	26.005
Coeff. of silage		66.4	68.3	50.2	73.6	62.5	73.3
*Animal No. 3**							
In hay	64.000	55.558	51.219	1.073	1.061	20.884	22.568
In silage	445.884	107.636	100.424	1.597	2.788	27.749	59.910
Total	509.884	163.194	151.643	2.670	3.849	48.633	82.478
In feces	402.081	64.980	57.774	1.217	1.397	23.120	25.973
Digested		98.214	93.869	1.453	2.452	25.513	56.505
Coefficient		60.2	61.9	54.4	63.7	52.5	68.5
Dig. from hay		28.612	26.890	0.631	0.410	8.730	13.699
Dig. from silage		69.602	66.979	0.822	2.042	16.783	42.806
Coeff. of silage		64.7	66.7	51.5	73.2	60.5	71.5
Animal No. 4							
In hay	90.000	78.129	72.027	1.509	1.492	29.369	31.736
In feces	208.923	37.621	34.145	0.617	0.971	16.993	12.385
Digested		40.508	37.882	0.892	0.521	12.376	19.351
Coefficient		51.8	52.6	59.1	34.9	42.1	61.0
PERIOD 6							
Animal No. 1							
In silage	264.000	62.674	58.857	1.000	1.774	17.511	33.324
In feces	120.803	20.413	18.180	0.422	0.559	6.516	8.667
Digested		42.261	40.677	0.578	1.215	10.995	24.657
Coefficient		67.4	69.1	57.8	68.5	62.8	74.0
Animal No. 2							
In hay	48.000	42.091	38.829	0.808	0.753	16.100	16.925
In silage	60.000	14.244	13.377	0.227	0.403	3.980	7.574
Total	108.000	56.335	52.206	1.035	1.156	20.080	24.499
In feces	145.764	24.526	22.265	0.441	0.591	10.546	8.464
Digested		31.809	29.941	0.594	0.565	9.534	16.035
Coefficient		56.5	57.4	57.4	48.9	47.5	65.5
Dig. from hay		21.677	20.385	0.475	0.291	6.730	10.273
Dig. from silage		10.132	9.556	0.119	0.274	2.804	5.762
Coeff. of silage		71.1	71.4	52.4	68.0	70.5	76.1

* Collection period of 16 days.

TABLE 25.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY FOR EXPERIMENT 3—*Conc.*
(Collection period of 12 days; weights in kilogrammes; coefficients in per cent)

—	Original weight	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract
			PERIOD 6—*Concluded*				
Animal No. 3							
In hay	48.000	42.091	38.829	0.808	0.753	16.100	16.925
In silage	120.000	28.488	26.753	0.454	0.806	7.960	15.147
Total	168.000	70.579	65.582	1.262	1.559	24.060	32.072
In feces	156.651	29.700	26.706	0.542	0.728	12.129	10.686
Digested		40.879	38.876	0.720	0.831	11.931	21.386
Coefficient		57.9	59.3	57.1	53.3	49.6	66.7
Dig. from hay		21.677	20.385	0.475	0.291	6.730	10.273
Dig. from silage		19.202	18.491	0.245	0.540	5.201	11.113
Coeff. of silage		67.4	69.1	54.0	67.0	65.3	73.4
Animal No. 4							
In hay	48.000	42.091	38.829	0.808	0.753	16.100	16.925
In silage	192.000	45.581	42.805	0.727	1.290	12.735	24.235
Total	240.000	87.672	81.634	1.535	2.043	28.835	41.160
In feces	213.876	35.401	31.595	0.671	0.928	13.382	13.240
Digested		52.271	50.039	0.864	1.115	15.453	27.920
Coefficient		59.6	61.3	56.3	54.6	53.6	67.8
Dig. from hay		21.677	20.385	0.475	0.291	6.730	10.273
Dig from silage		30.594	29.654	0.389	0.824	8.723	17.647
Coeff. of silage		67.1	69.3	53.5	63.9	68.5	72.8
			PERIOD 7				
Animal No. 1							
In hay	48.000	42.139	39.012	0.847	0.796	15.832	17.087
In silage	264.000	65.762	61.218	1.160	1.697	18.085	34.190
Total	312.000	107.901	100.230	2.007	2.493	33.917	51.277
In feces	280.024	45.709	40.466	0.909	1.175	17.008	16.972
Digested		62.192	59.764	1.098	1.318	16.909	34.305
Coefficient		57.6	59.6	54.7	52.9	49.9	66.9
Dig. from hay		21.702	20.481	0.498	0.307	6.618	10.372
Dig. from silage		40.490	39.283	0.600	1.011	10.291	23.933
Coeff. of silage		61.6	64.2	51.7	59.6	56.9	70.0
Animal No. 2							
In hay	48.000	42.139	39.012	0.847	0.796	15.832	17.087
In silage	313.000	77.968	72.580	1.375	2.012	21.441	40.536
Total	361.000	120.107	111.592	2.222	2.808	37.273	57.623
In feces	316.236	47.490	42.147	0.985	1.282	17.030	18.013
Digested		72.617	69.445	1.237	1.526	20.243	39.610
Coefficient		60.5	62.2	55.7	54.3	54.3	68.7
Dig. from hay		21.702	20.481	0.498	0.307	6.618	10.372
Dig. from silage		50.915	48.964	0.739	1.219	13.625	29.238
Coeff. of silage		65.3	67.5	53.7	60.6	63.5	72.1
Animal No. 3							
In hay	90.000	79.011	73.148	1.589	1.493	29.684	32.039
In feces	183.137	37.559	34.025	0.626	0.785	17.461	11.929
Digested		41.452	39.123	0.963	0.708	12.223	20.110
Coefficient		52.5	53.5	60.6	47.4	41.2	62.8
Animal No. 4							
In silage	264.000	65.762	61.218	1.160	1.697	18.085	34.190
In feces	133.072	21.424	18.804	0.464	0.566	6.817	8.645
Digested		44.338	42.414	0.696	1.131	11.268	25.545
Coefficient		67.4	69.3	60.0	66.6	62.3	74.7

* Collection period of 16 days.

DISCUSSION

From the data obtained in Experiments 1 and 3, it is evident that with the exception of nitrogen and ether extract, as the plane of nutrition was increased the digestibility of the silage decreased whether it was fed alone or with hay as a basal ration. (See tables 2, 3, 13, and 14.) The decrease in value of the silage was of the order of 6 to 8%. Using the coefficients of digestibility of the organic matter as a criterion and keeping in mind that the experiments were done in different years, the course of the change in digestibility was similar in both cases. When the silage was fed alone, the amounts consumed varied approximately from 8 to 26 kilogrammes per animal per day and the digestibility of the organic matter decreased approximately from 72% to 66% for the 4 × 4 randomized square. In the third experiment where hay was fed as a basal ration, the quantities of silage consumed varied approximately from 5 kilogrammes to 28 kilogrammes and the digestibility of the organic matter decreased approximately from 76% to 68%.

The results in Experiment 2 were slightly different. The range of the coefficients of the digestibility of the organic matter of the corn silage was practically the same as in the third experiment, namely, from about 76% to 68%. However, the amount of silage consumed varied only from 2.5 kilogrammes to about 8.5 kilogrammes. This, of course, was due to the fact that the hay was increased to maintain a constant ratio to the corn silage. In a previous publication (3) it was shown that hay could be fed to steers from 2.5 kilogrammes up to 9.0 kilogrammes without its digestibility being significantly affected. At the highest level, however, in that experiment, there was a slight lowering in digestibility. If there should be in this present instance a theoretical lowering of something less than one absolute per cent in the digestibility of the hay, then it would tend to exaggerate the range of the calculated coefficients of silage in Experiment 2. Again the calculated values in Experiment 2 are subject to large errors and the range given of 76% down to 68% may be more exaggerated than the true one. The more important point of Experiment 2 is its application to Experiment 3 in determining whether or not the changing ratio of hay to silage had any influence on digestibility. The ratio of hay to silage chosen for Experiment 2 was the same as that of Level I in Experiment 3, namely, 4 : 5 (see Tables 13 and 14).

If, then, the ratio of hay to corn silage fed at Level I in Experiment 3 were maintained constant but the total quantity increased, the calculated coefficients of digestibility of the corn silage would decrease. Presumably the values obtained at the other levels would similarly vary with the absolute quantities fed. This is reasonable evidence that it is the plane of nutrition and not the ratio of hay to corn silage which determines the magnitude of the coefficients of digestibility.

As far as any associative effects between corn silage and hay are concerned, it will be noticed in Experiment 3 that the coefficients of digestibility of corn silage when fed alone were, with the exception of nitrogen, similar to the means of the calculated values. As shown by Experiment 1, these values for corn silage alone would vary with the quantity fed in a manner similar to that of the values calculated from the ration with hay. There

does not appear to be any associative effect between hay and corn silage. This question will receive more detailed consideration in a subsequent paper.

The digestibilities of the nitrogen and ether extract of the silage were not sensibly affected by the plane of nutrition. One consideration, of course, is that they were only present in silage in relatively small amounts. While, therefore, the quantity of silage consumed reached the limit of the animals' capacities, the absolute quantities of nitrogen and ether extract in the digestive tract were not very great.

From a practical standpoint it may be concluded from this paper that when silage is fed to animals in very large amounts, a loss in value of some 6% may be expected.

From the theoretical standpoint, it is recommended that silage should not be used as a basal ration in determining the coefficients of digestibility of feeds.

SUMMARY AND CONCLUSIONS

In three experiments grade Shorthorn steers were fed corn silage ta various levels either alone or with hay.

As the plane of nutrition increased, the digestibility of the organic matter, dry matter, crude fibre, and nitrogen-free extract decreased.

The plane of nutrition had no statistically significant effect upon the digestibility of nitrogen or ether extract.

The decrease in money value of the corn silage from the lowest to the highest plane was of the order of 6 to 7%.

ACKNOWLEDGMENT

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BOOK REVIEW

PROCEEDINGS OF THE FIFTH INTERNATIONAL CONFERENCE OF AGRICULTURAL ECONOMISTS. Oxford University Press, Oxford, England, 1939.

The Proceedings of the Fifth International Conference of Agricultural Economists held at Macdonald College, Quebec, Canada, in August, 1938, is now available in a 450-page volume by the Oxford University Press of Oxford, England and Toronto, Canada. This volume contains a complete record of the proceedings including both formal papers, and the discussion. With over five hundred in attendance and a score of countries represented, the discussion by representatives of various countries of the main topics provides in this record particularly interesting and comprehensive pictures of the subjects of discussion.

The main topics discussed at the conference were outlined by two principal speakers and discussed by several representatives of various countries. Subjects treated in this way included:

1. The Social Implication of Economic Progress in Agriculture.

The two main papers on this topic were given by J. F. Booth, of Ottawa, Canada, and M. L. Wilson, Assistant Secretary of Agriculture of the United States, Washington. These two papers stressing the social aspects of the economic status of agriculture elicited a spirited discussion—the contributions of nine are reported in the proceedings. This discussion included an important contribution by R. D. Craig of the Dominion Forest Service, on the importance of forestry in agricultural economy.

2. Social Control of the Use of Land.

Main papers on this subject were by C. von Dietze of the University of Freiburg, Germany, and by Hency C. Naylor, Farm Foundation, Chicago. The discussion participated in by eleven delegates from six different countries reveals the wide variation in the system of tenure, the organization of farming and the numerous problems evolving in different places.

3. *Farm Labour and Social Standards.*

The two main papers dealing with this question were given by F. von Bulow, of the League of Nations, Geneva, and J. F. Duncan, Secretary of the National Farmers Union, Scotland. The discussion of these papers includes contributions from representatives of Britain, United States, Germany, Bulgaria, India, Trinidad and British West Indies. Among those who discussed this problem was included an operator of a dairy farm in England, an employer of considerable hired labour for this type of farming.

4. International Trade in Relation to Agriculture

The leading papers on this problem were presented by H. A. Wallace, United States Secretary of Agriculture, and G. Minderhoud of Holland. Both the leading papers and the discussion ensuing stressed the difficulties hampering trade between nations in farm products and the need for some international agreement to ensure increased trade in these products and a higher standard of living generally.

Included in the proceedings also are some papers on special subjects. These include a discussion of taxation by B. H. Hibbard of Madison, Wisconsin, a paper on Mexican Agrarian Reform by Ramon Fernandez of Mexico, an outline of the Economic Organization of Agriculture in Argentine by Paul H. Nyhus, Agricultural Attache of the United States at Buenos Aires, a discussion of Co-operation in Canada by A. E. Richards, Ottawa, and a paper on Seigniorial Tenure in Canada by C. Gagne of Ste. Anne de la Pocatiere, Quebec. Those interested in governmental relations to agriculture, while they will find references to this subject throughout the volume, may find the discussion of Recent Agricultural Experience in the Irish Free State by Senator J. Johnson of Dublin, and the discussion by Mr. A. H. Cockayne of Recent Changes in New Zealand's Economic Policy, particularly interesting. Even this brief outline of the contents may, it is hoped, indicate in some measure the value of this volume as reference work on problems of agriculture as viewed by outstanding authorities of different lands.

—J. E. Lattimer.

BULLETINS

The Action and Use of Colchicine in the Production of Polyploid Plants—J. L. Fyfe.

The discovery of the action of the drug colchicine on nuclear division, making it the most reliable agent yet used in the production of polyploid plants, has excited great interest even in laymen and is of importance to those working on the cytology or genetics of plants.

The Imperial Bureau of Plant Breeding and Genetics, Cambridge, has issued a bulletin on the subject, summarizing the already fairly extensive literature. This bulletin begins by explaining the chromosome doubling; next a detailed account of the action of colchicine on mitosis and meiosis is given, followed by summaries of the results obtained from the use of colchicine for producing pollyploid plants. The action and use of acenaphthene; which the Russian workers have shown to be a similar agent to colchicine are also described. Particular attention has been paid throughout to treatments and dosages and some recommendations are given which should be helpful to those contemplating the production of polyploids. All the literature appearing up to the end of January 1939 is included and listed in a bibliography of 38 references.

The very reasonable price (1s.) of the bulletin deserves mention.

Bibliography of Baking Quality Tests (Supplement).

The valuable "Bibliography of Baking Quality Tests" issued by the Imperial Bureau of Plant Breeding and Genetics in 1934 has been brought up to date by the publication of a supplement which contains titles of papers from 1933 to 1938 inclusive.

Some of the papers noted have been abstracted in "Plant Breeding Abstracts" but many, because of their specialist nature, have not been reviewed but will thus become available to workers on the subject.

A note of volume and abstract number in the margin indicates where an abstract may be found in "Plant Breeding Abstracts". The titles are arranged alphabetically according to authors and given sufficient demand, further supplements are promised from time to time.

CARBON DIOXIDE RESEARCH PROJECT

The time-honoured method of preserving food by storage in low temperature rooms can be materially improved by the addition of carbon dioxide to the atmosphere. That a harmless gas, the waste by-product of metabolic processes, can be used to restrain the growth of micro-organisms and concomittant spoilage, is a most interesting and novel, but entirely practical technique.

This method, known as gas storage, while new to the Americas, has been applied commercially on a large scale in England for some time. Some two hundred plants applied the method to such a varied list of food products as fish, fruit, vegetables, eggs, dairy products and meat last year. It should be of great significance to the meat packers, the largest industry in the United States, that Australia and New Zealand shipped to England in 1937 a total of 75,000,000 pounds of chilled beef in gas storage, the product arriving after an average trip of twenty-eight days, in better condition, colour and bloom, than ever before.

Scientific workers in the field of bacteriology have been familiar with the effect of carbon dioxide atmospheres for many years. Strangely enough, carbon dioxide is used as an aid in growing certain "microaerophilic" bacteria at incubation temperatures, but this same gas, even in small amounts, when present in a refrigerator will materially slow down, and even suppress the development of micro-organisms responsible for food spoilage.

Mallmann, of the Michigan Agricultural Experiment Station, reports in studies now in progress on pure cultures of meat spoilage micro-organisms marked inhibition of development. Stewart, of Iowa Agricultural Experiment Station, has found in commercial tests that eggs held in gas storage had better interior quality than eggs stored at the same temperature under present conditions. Brooks, of the Bureau of Plant Industry, United States Department of Agriculture, and Allen, of the California Agricultural Experiment Station, and many others, particularly the English workers, have shown that fruit can be stored and shipped more successfuly in an atmosphere of carbon dioxide than by the usual methods now in common use.

Failure to apply this knowledge on a commercial scale has been due primarily to lack of automatic devices for the control of gas concentration, it having been demonstrated that there is a different optimum concentration for each food if maximum efficiency is to be obtained. After much research this deficiency has been corrected. There are now available inexpensive automatic controls that function with precision, the manufacture of which awaits only the details of specific needs by the various food industries. This whole development has also stimulated interest in new methods of handling carbon dioxide, and industry now has at its disposal converters for changing dry-ice into gas at substantial savings over the use of cylinder gas. Keen interest has been shown by manufacturers of refrigerating equipment, some of whom have made installations available for study of the relationship between concentration of gas and temperature.

Although gas storage in connection with refrigeration has been proved commercially feasible and economically sound, it still must pass through

careful laboratory inspection and field test to assure safe and dependable commercial usage. Two avenues of applying gas storage to commercial practice are open: FIRST, the generally practiced method of "trial and error" by each industry, and perhaps every member of each industry, working alone. Obviously such duplication of effort is expensive and time consuming. SECOND, collective planned organized research by the best minds in the industries and scientific laboratories working together, subsidized by small fees from all of the industries that will be benefited. This is the efficient, modern, democratic approach to problems common to a large group.

The successful application of gas storage for the preservation of perishable foods means the establishment of higher humidities in the storage room, which in turn, means less "shrinkage"; the elimination of "surface" microbial spoilage; the possibility of higher temperatures for refrigeration which means a lessening of storage cost, and the ultimate goal of better quality products. That a contribution of this magnitude will mean greater consumer acceptance and improved profits, there can be no doubt.

To attain the objective of determining the basic principles of gas storage, and reducing these principles to practical economical applications in a minimum time, the American Institute of Refrigeration has sponsored a Carbon Dioxide Research Project and appointed the nucleus of a General Committee, consisting of outstanding authorities in the various food fields: Dr. E. H. Harvey of Wilson & Co., heads the committee, with Dr. M. E. Pennington, Dr. S. C. Prescott, Mr. Gardner Pool and Mr. G. A. Horne, as members. Every member of this group, representing the scientific laboratories and the refrigeration industry, is contributing his time and advice without remuneration, for the purpose of advancing this development as rapidly as possible.

The general Committee will have complete charge of the Carbon Dioxide Research program and will assign research work and allot the money to be spent on each major food product. Advisory Committees, for each of the major food products, will meet regularly to make recommendations to the General Committee.

That industry and the Agricultural Experiment Stations are ready for such a type of co-operative research is indicated by the fact that already in the laboratories of the Bureau of Plant Industry, United States Department of Agriculture, and the state agricultural experiment stations of Michigan, Indiana and Minnesota, refrigeration equipment, controls and converters have been installed and work is in progress. Immediate research projects on other leading food products are under consideration for Wisconsin, Iowa, Florida, Texas, California, Oregon and Washington state agricultural experiment stations, and also the Massachusetts Institute of Technology.

A more comprehensive and forward-looking program has probably never been developed. From practical industrial and commercial applications, an economic demand may be created for controlled and maintained carbon dioxide gas concentrations, as a further preservative for the storage and transportation of all manner and kind of perishable food products. Protection on the new discoveries, methods and processes established from the many research projects, will give to the various divisions of the food

field who subscribe to this program, an opportunity to apply these possible benefits to their specific needs.

Gas storage is not a panacea for all the ills afflicting those engaged in the processing, transportation and storage of foodstuffs. That it will be a contribution to certain troublesome features involving spoilage is much to be hoped and expected; the character of those responsible for directing the general plan is a guarantee of that. Money is needed to underwrite the expense of the research. It is fervently hoped industry will seize this opportunity to support a project headed by themselves and conducted by themselves, with the assistance of tax-supported institutions.

The writer and members of the General Committee will be glad to answer and clarify any questions pertaining to this Co-operative Research Program.

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